H. A. Standma

With the compliments of the au

V.

I. EXPERIMENTS ON THE EFFECT OF FREEZING AND OTHER LOW TEMPERATURES UPON THE VIABILITY OF THE BACILLUS OF TYPHOID FEVER, WITH CONSIDERATIONS REGARDING ICE AS A VEHICLE OF INFECTIOUS DISEASE.

II. STATISTICAL STUDIES ON THE SEASONAL PREVALENCE OF TYPHOID FEVER IN VARIOUS COUNTRIES AND ITS RELATION TO SEASONAL TEMPERATURE.

BY

ILLIAM T. SEDGWICK, Ph. D., and CHARLES-EDWARD A. WINSLOW, S. M.,
Professor of Biology, *Instructor in Biology,*

In the Massachusetts Institute of Technology,
BOSTON, MASSACHUSETTS.

WITH EIGHT PLATES.

Presented March 12, 1902.

(Preliminary Communication, December 13, 1899.)

TABLE OF CONTENTS.

PART I.

PART II.

PART III.

PART I.

I. INTRODUCTORY.

In view of the fact that the micro-organism which is commonly considered to be the cause of typhoid fever appears to be able to survive for longer or shorter periods in the environment of man, it becomes important to discover, as nearly as may be, its behavior under various natural conditions. Some knowledge of this kind we have already in the case of heat and light; some, also, in respect to low temperatures under certain conditions. But a careful review of the present state of our knowledge in regard to the influence of cold upon the bacillus of typhoid fever shows that much still remains to be done in order to make our knowledge in this direction more precise.

The subject assumes great practical importance when we begin to consider the influence of external conditions upon the longevity of the bacillus in nature, particularly in those regions in which there is a considerable variation of climate. It was a theory formerly widely held that the specific organism of typhoid fever was not only capable of enduring for a long time outside the human body, but even that a residence in earth, filth heaps, and the like was an essential phase in its life history. Modern researches have thrown grave doubt upon this earlier theory, but at the same time rigid inquiry into epidemics and further knowledge of the disease itself have shown how readily the micro-organism may become widely distributed in the environment. Prolonged and careful studies of the influence of temperature upon the bacillus of typhoid fever, have led us to believe that this factor plays a part in the seasonal distribution of the disease which is of the highest importance, making it possible to explain, by the co-operation of this and other factors, such as light and dryness, certain phenomena hitherto inexplicable or little understood. An obvious and direct application of the principles worked out concerns one of the principal food supplies of man, and an important section of the following paper is therefore devoted to a consideration of the danger of the conveyance of the disease in question by polluted ice.

II. A REVIEW OF THE LITERATURE RELATING TO ICE AS A VEHICLE OF DISEASE AND TO THE BACTERIOLOGY OF ICE.

A. INFECTIOUS DISEASES ATTRIBUTED TO POLLUTED ICE AND ICE-CREAM.

THE interest of the authors in this subject was first aroused by the practical questions connected with ice supply and the public health. As will appear in the paragraphs immediately following, diseases, and particularly typhoid fever, have not infrequently been attributed to impure ice.

The first outbreak of disease directly ascribed to this source was reported in this country in 1875,(1) at the summer resort of Rye Beach. Dr. Nichols of Boston, who was called in to investigate the affair, found the illness, a more or less severe intestinal disorder, confined to the guests of one of the two large hotels of the place. The other hotel and adjacent cottages were unaffected. The milk and water supplies and the drainage appeared above suspicion. The ice for the hotel, however, was cut on a small pond whose waters were rendered very foul by a mass of putrescent matter, composed of marsh mud and decomposing sawdust. A chemical analysis of the ice, and of the water from the pond, showed high total organic matter and high ammonia, both free and albuminoid. Three cases of the disease outside the hotel directly following the use of this ice made the evidence still stronger. Three years later Dr. Smart, U. S. A.,(2) attributed some cases of a "malarial remittent fever" in a Rocky Mountain army post to the contamination of mountain streams by melting snow. The high organic content of the water in early spring was probably due to this cause, and he believed that the "*materies morbi*" of malaria had a similar origin. In the summer of 1879 an outbreak of dysentery occurred in Connecticut which is discussed in the Second Report of the Board of Health of that State.(3) Out of the eleven persons, including the family residing in a certain farmhouse, two hired men, and relatives who came to assist in nursing, there were eight cases of dysentery, three of them fatal, and two cases of persistent diarrhœa. The drinking water in use gave satisfactory results on analysis, but the soil adjoining the house was damp and polluted, and the ice used came from a small stream which served as a running place for pigs. Analysis of the ice-water showed high ammonias, and this appeared to the investigators the most probable cause of the disease. In the Report of the same Board for 1882,(4) an interesting single case of typhoid fever is cited as probably derived from ice. The patient had lived alone for some months in a house whose sanitary conditions were apparently perfect. He was inordinately fond of ice-water, and the ice for his house was cut on a small pond near by. It appeared on investigation that the drains from some laborers' houses emptied directly into the pond, and that in these houses there had been three cases of typhoid fever during the previous summer. Attention was also called to the general danger from ice supply, by the Connecticut State Board of Health in 1880, by the Massachusetts State Board in 1876 and 1889, by the Michigan Board in 1882 and 1884, by the New Hampshire Board in 1882, the New York Board in 1886, the Minnesota Board in 1886, and the sanitary authorities of Chicago in 1896 and of Milwaukee in 1876.

Duclaux (5) appears to have been the first European to give the matter marked attention, although a recent French writer (7) mentions an ice epidemic at "Eveshem," in 1882, of which we have found no other account. Duclaux enlarged at length upon the danger from ice, especially the artificial ice made in Paris from the water of certain highly polluted canals. In 1893 Professor Riche (6) made a long report to the *Conseil d'hygiène et de salubrité de la Seine* upon the dangers to the inhabitants of Paris from the sale of highly polluted ice. He quoted a letter from Pasteur as follows: "Le docteur Roux vous a dit son opinion, et c'est aussi la mienne, que toute eau impropre à la boisson l'est également pour préparer, en hiver, de la glace pour l'alimentation. Les microbes inoffensifs ou pathogènes résistent presque tous à des températures même très basses." M. Riche showed that much of the Paris ice came from contaminated sources, and recommended strong legal restrictions upon its sale. Finally, Dr. Dorange, in the *Revue d'Hygiène*,(7) described a supposed ice-epidemic of typhoid fever at the military post of Rennes in the autumn of 1895. Eight lieutenants of the regiment there stationed were taken ill between the twelfth and the twenty-fifth of December. The fact that these officers did not habitually live in common but had all been present at a regimental banquet upon the fourth of December, pointed to that occasion as the moment of infection. The higher officers dined in a separate room, and used no water but the town supply, which was excellent. The lieutenants, on the other hand, drank a "tisane" of champagne mixed with chilled water. The man who provided this claimed that it also was derived from the regular town-supply. The fact that the town water could be obtained by him only from a considerable distance and under strict police regulations, led Dr. Dorange to suspect that he had made use of the water in a reservoir which stood in the room where he cooled his decanters and which received the meltings from his stock of ice. The ice supply of the town was considered highly polluted. The additional facts are cited that the menus of the different classes of officers were the same, and that certain of the petty officers who did not drink from the "tisane" but made use of beer instead, escaped the disease.

Altogether it appears probable that the milder intestinal disorders, caused by mere decomposing organic matter and not by specific germs, have at times been caused by polluted ice. The Rye Beach epidemic was carefully and thoroughly studied, and leads directly to that conclusion. With respect to typhoid fever the case is different. The only ice-epidemic of typhoid fever which has come to our notice, viz., that at Rennes, rests on a doubtful chain of circumstances, and lacks the confirmation of a complete exclusion of all possible factors other than ice. We have been unable, then, to find any conclusive evidence that typhoid fever has been caused by polluted ice-supply.

A number of English epidemics of typhoid fever, more or less clearly traced to ice-cream, should be noticed here, although the conditions are quite different from those which obtain in the case of ice. The first of these epidemics occurred in the English sanitary districts of Greenwich and Rotherhithe in 1892.(8) During the last week of September and the two months next following 511 cases were reported, the beginning of the attack in 15 per cent of the cases falling on October 1 and in 57 per cent of the cases falling in the fortnight preceding October 3. A remarkably large proportion of the victims were young children. The water supply and sewerage of the four separate foci of infection were different and apparently all in good condition. The milk supply of the households attacked came from seven dairy farms, and in many cases consisted only of condensed milk. Suspicion was then directed to the ice-cream sold by Italians from barrows in the street. A careful canvass of one neighborhood in which 56 cases of typhoid fever had occurred showed that 924 persons lived in houses where ices had not been eaten, 232 lived in houses where ices had been obtained from shops, and 395 in houses where ices had been obtained from a certain ice-cream vendor. All the cases of typhoid fever were in this latter class. A detailed examination of the cases in all the infected areas showed that 88.9 per cent of the sufferers had eaten ices, and that, of these, 91.4 per cent had obtained their supply from ten Italian vendors living in a certain Mill Lane, of whom one was the dealer above mentioned. The sanitary conditions in Mill Lane were found to be abominable; and in the family of one of the purveyors of ice-cream two children had sickened with typhoid fever on July 29 and August 5 respectively.

An epidemic of typhoid fever which attacked over 800 persons in the county of Renfrew, in Scotland, in 1893, was attributed by Dr. A. C. Munro partly to ice-cream and partly to the public water-supply.(9) Out of the first 180 cases 63 were shown to have eaten ice-cream prepared by a dealer in whose family a case of typhoid fever had occurred during the previous month. The patient had been in intimate contact with the ice-cream business during the greater part of her illness.

Vaughan and Perkins, in 1895,(10) ascribed two epidemics of severe, but not fatal, intestinal disease to a new pathogenic bacillus which they isolated from ice-cream in one case and from cheese in the other. The germ belonged to the colon group, and the authors note that neither twenty-nine days of continuous freezing nor alternate freezing and thawing could destroy its vitality.

Dr. Hope, in 1898,(11) studied an epidemic affecting 27 school children in Liverpool in which the only clue appeared to be the presence of all the patients at a fair just at the time of infection. Here 24 of the children had eaten ice-cream and two more had partaken of "chip" potatoes sold by an Italian in whose house there had been two cases of typhoid fever.

In these cases of infection from ice-cream there is, of course, no certainty that the disease germs were actually frozen. The possibility of contamination from spoons, vessels, and the hands of the vendor might easily account for all the phenomena. Even if the infection was really carried in the ice-cream the exposure to a low temperature must have been a relatively short one. The same reasoning applies to the famous Plymouth, Pa., epidemic of typhoid fever. This little mining town had 1200 cases of the disease and 130 deaths among its 8000 inhabitants in 1885, and the investigation(12) clearly traced the infection to the dejecta of a single typhoid fever patient which were thrown out on the snow on the banks of the brook supplying the town with water, and which had been washed in by the first general thaw of the spring. It may easily have been that the discharges thrown out during the day or two preceding the thaw were never really frozen at all. In any case the conditions affecting germs imbedded in a solid mass of rich food material are quite different from those which obtain in the formation of ice upon a stream or pond.

B. BACTERIA IN NATURAL ICE, SNOW, AND HAIL, AND IN ICE-CREAM.

In spite of the absence of epidemiological evidence, it has been the common opinion of sanitarians that ice might be an important source of infection for typhoid fever or any other germ disease. Its apparent purity was shown by the earliest bacteriologists to be deceptive. Burdon-Sanderson,(13) in 1871, found that liquid culture media showed bacterial growth when inoculated with melted ice or with snow. In the next year, Cohn (14) described experiments in which nutrient solutions containing bacteria were not sterilized by exposure to a temperature ranging as low as –18° C. for about 6 hours or by a temperature with a minimum of –7° C. for 18 hours.

Professor Joseph Leidy, in 1884,(15) exhibited, at a meeting of the Academy of Natural Sciences at Philadelphia, snow water derived from melted ice, containing not only Infusoria but also Rotifers and Worms. Pohl, in the same year,(16) recorded the finding of many bacteria in snow and ice, 110 per centimeter in Neva ice, and 20,774 in one sample of bubbly ice. He also found bacteria in falling snow, the number decreasing with the continuation of the storm. A report on the ice supply of the city of Syracuse (17) was made to the New York Board of Health in 1886 in which the presence of a great number of bacteria was noted in ice from Onondaga Lake and the Erie Canal. In 1888 Breunig (18) found 1310–2760 germs in ice, and Kowalski (19) analyzed sixty samples of natural ice, and found from 10 to 1000 germs per cubic centimeter, no sample being sterile. Still another paper was published at this period, 1888–89, by Heyroth,(20) who studied the Berlin ice-supply, and, in 25 samples, found from 2 to 133,000 bacteria per cubic centimeter, the highest figures corresponding to chemical analyses which showed the most marked pollution. An elaborate report was made by the State Board of Health of Massachusetts in 1889,(21) in which 238 samples of natural ice from the ponds and streams of this State were analyzed bacteriologically. The figures for ice from different portions of the cake were as follows: —

	Number of Samples.	Bacteria per c.c.		
		Maximum.	Minimum.	Average.
Transparent Ice	27	893	0	105
Clear Ice	75	370	0	15
Bubbly Ice	113	1950	0	111
Snow Ice	23	2968	0	622

A "Lancet" analytical sanitary commission made an examination of some ice sold in London in 1893, and found that while all the specimens gave good chemical analyses, two out of the six examined contained 400 to 700 bacteria per cubic centimeter.(22)

Girard and Bordas(23) published some startling analyses of the Paris ice-supply also in 1893. They found a minimum of 23,000 colonies and a maximum of 100,000 colonies per cubic centimeter, including the Bacillus coli communis and a pathogenic vibrio. These quantitative results are so large as to suggest that the samples were probably not planted promptly after melting.

Christomonas(24) has recently studied artificial ice, and reports that when water containing 71 bacteria per centimeter was frozen, 450 germs per centimeter were found in the central core and 8–10 in the clear ice at the sides.

The bacteria of snow and hail have also received considerable attention. Soon after the work of Pohl,(16) Janowsky(25) made analyses of old and of freshly fallen snow in the neighborhood of Kiew, and found bacteria in both, less in the former than in the latter. Schmelk(26) studied the bacterial life in the snow of a Norwegian glacier and in the chill streams flowing therefrom; and in a later paper(27) he recorded small numbers in both snow and ice at Christiania. Bujwid(28) found 21,000 bacteria per cubic centimeter in the analysis of a melted hail-stone; and Foutin(29) in Russia obtained similar, though smaller, figures.

Giacosa(30) found bacteria present in small numbers in snow lying at an elevation of 3800 meters above the sea, and Abbott(31) noted 703 colonies per cubic centimeter in hail. Dominguez,(32) in 1892, published a paper on the bacterial content of hail; and finally, Scofone,(33) who accompanied a scientific expedition to Monte Rosa in 1894–95, recorded the presence of small numbers of bacteria in melted snow obtained from high altitudes. In the following year he gave the results of some examinations made on a plateau 2460 meters above the sea, which confirmed his previous conclusion that the bacteria in the deeper layers of the snow were somewhat more numerous than in the superficial layers.(34)

The number of bacteria present in ice-cream has been shown at times to be enormous. Klein(35) found the germ content of London ice-cream very high, and B. coli communis frequently present. Nield-Cook(36) recorded from 5,000,000 to 14,000,000 germs per cubic centimeter in ice-cream from the same source, the majority being colon bacilli. Stevenson(37) testified, at the trial of an Italian ice-cream vendor, that he had found over 4000 germs per cubic centimeter, of which three proved to be B. coli communis. Wilkinson(38) reached similar results, and quoted, without reference, the following results of other observers: —

Macfadyen	119,000 — 7,000,000	bacteria per cubic centimeter.
Kanthack	8,000,000 — 13,000,000	" " " "
Foulerton	500,000 — 7,000,000	" " " "

In this connection it may be interesting to note the very small numbers of bacteria present in the air and water of the Arctic regions. Nystrom(39) discovered this fact in 1868 by the exposure of a number of flasks of putrescible matter, after the manner of Pasteur. Couteaud (40) found but one colony in 19 flasks exposed to Arctic air, the experiment being carried on, however, on the open sea, so that the result is not surprising. He also found but few species present in some analyses of water and of soil. In the Nansen expedition the poverty of the bacterial flora of the air was noted. Finally, Dr. Levin (41) of Stockholm made an elaborate study of the subject with the Natthorst expedition. In 21,600 liters of air examined at twenty different places 3 germs alone were found, all in one sample. In sea water, at the surface, 11 germs per centimeter occurred, belonging apparently to two characteristic species. Fresh water and melted ice and snow gave similar small numbers. Samples from considerable depths in the ocean showed somewhat higher numbers than were obtained at the surface. Finally, tests of the alimentary canals of various Arctic animals and birds showed many of them to be completely sterile.

C. EXPERIMENTS ON THE EFFECT OF FREEZING AND OTHER LOW TEMPERATURES UPON THE VIABILITY OF BACTERIA.

Laboratory experiments have confirmed the conclusion, drawn from the examination of natural ice, that freezing is by no means always fatal to germ life. Von Frisch (42) froze putrefying solutions and reduced the frozen mass to a temperature of –87° C., and after some hours found that sterilization had not ensued.

Pictet and Young (43) subjected bouillon cultures of several species to a temperature below –70° C. for 108 hours, during twenty hours of which time the temperature was below –130°. After this treatment B. anthracis and the bacillus of "charbon symptomatique" were alive and virulent; B. subtilis and B. ulna grew readily; half the inoculations made from the cultures of two species of micrococci grew and half did not. Finkler and Prior (44) stated that the vibrio described by them could survive a temperature of –4° C. for many days. McKendrick,(45) in a communication to the British Association in 1885, noted that putrescible liquids were not sterilized by a temperature of –84° C. Forster (46) found that the phosphorescent bacteria which he isolated from fish preserved by cold storage grew vigorously at 0° C. Fischer (47) isolated 5 species of bacteria from the water of the harbor at Kiel, and 9 other forms from the soil, all capable of multiplying at 0°. In the research already cited,(20) Heyroth froze gelatine stick-cultures of various species for from seven to ten days, and then placed them once more under favorable conditions; out of 30 species, thus treated, 25 showed growth, though 5 of these had partially lost their liquefying power. D'Arsonval,(48) in 1891, recommended liquefied carbonic acid for use in sterilizing organic extracts, and stated that when the treatment is prolonged, especially if broken by a return to 40° for a time, "nothing living can resist it," but his own and other later researches showed the error of this conclusion. Forster, in 1892,(49) examined various natural waters, foods, wastes, sweepings, and soils for bacteria capable of growth at 0°, and found a few such forms in water, earth, and street sweepings. When present at all they occurred in great numbers. Forster also demonstrated the multiplication of bacteria and the progress of decomposition in butcher's meat chopped up and kept in an ice calorimeter. Fischer(50) noted that Miller's vibrio and the vibrio of Finkler and Prior could withstand a freezing temperature for some days.

Pictet, in 1893,(51) studied the effect of cold on plants and animals of the most widely separated classes. Of the bacteria he subjected 30 to 35 species to temperatures ranging as low as –200° C. by immersing them in liquid air, but the viability of the germs used appeared unaffected after "prolonged" treatment of this sort. D'Arsonval and Charrin(52) subjected cultures of Bacillus pyocyaneus to a temperature of –40° to –60° C. with the result that, in six out of eight instances, the germs remained alive.

In another paper(53) these authors mentioned that Bacillus pyocyaneus after exposure to –40°, –60°, and –95° C. exhibited profound changes in morphology and physiology. For some generations the descendants of the frozen germs showed elongated, ovoid, and other abnormal forms, and their colonies on gelatine were also of unusual character. Weber(54) noted that Hofer's bacillus, producing a contagious disease among Crustacea, can endure a temperature of –40° C. for four hours, as well as repeated thawings and freezings.

Professor Mason(55) recorded the exposure of cultures of "ordinary bacteria" to the temperature of solid carbon dioxide for many hours without causing their destruction. Still more recently Ravenel(56) submitted cultures of the anthrax, diphtheria, and typhoid bacilli, and of Bacillus prodigiosus to the temperature of liquid air, 191° below zero Centigrade, for periods of three hours, thirty minutes, one hour, and one hour respectively; in no case could any weakening of the vegetative power of the culture be detected.

Besides Pictet and Young(43) and Ravenel(56) a number of other observers have tested the effect of low temperatures upon specific pathogenes. Cadéac and Malet(57) found that tuberculous matter kept frozen for four months still produced characteristic symptoms in guinea pigs. In some work on the spores and vegetative forms of Bacillus anthracis carried out by one of the Franklands and Dr. Templeman,(58) it was found that a single freezing at –20° C. reduced the numbers present in water from

15,000 to 3500 per cubic centimeter, and after 29 successive freezings, extending over a period of three months, 3000 germs per centimeter could still develop. Evidently the vegetative forms were killed by one freezing, and the spores, not at all. Another culture which was spore-free showed reduction from 8000 germs per centimeter to 2 per centimeter after one freezing, sterilization following the second freezing.

Gabritschewsky, Wladimiroff, and Kressling and Gladin quoted by Kasansky (59) found that the plague germ could bear an artificial cold of −22° C. for two hours and natural cold ranging from 0° to −20° C. for from twelve to forty days. Kasansky himself in 1897–98 made some interesting experiments on the resistance of the specific organisms of plague and diphtheria against cold. The cultures were placed outside the window of the laboratory at Kasan, sheltered from light but exposed to the winter's cold, which ranged from a maximum of 5° C. to −34° C. Bouillon cultures of the plague germ showed life after thirty-two days; four months' exposure sterilized most of the tubes, but in one case growth was obtained after six months. Of the agar cultures tested some died in four months, and others contained living germs after five months and a half. Sixteen bouillon tubes of the diphtheria bacillus were kept for six months under similar conditions, and one tube only showed growth at the end of that time; two of the others, however, still gave positive results on the fifty-third and one hundred and eighteenth day, respectively.

Abel (60) exposed cultures of the diphtheria germ on blood serum and on dried threads to the winter's cold at Greifswald, and compared them with cultures kept in the room in the same condition. The first race used persisted on the blood serum for the whole period of eighty-six days both in the room and out of doors, although in the second case the growth obtained was meagre after the fiftieth day. The dried germs had disappeared by the sixty-eighth day out of doors and by the seventy-fourth indoors. Of the second race the serum culture remained alive in the room all through the experiment; the frozen one showed no growth after the seventy-fourth day. The threads gave living germs up to the seventy-fourth day in-doors and up to the fifty-sixth day out-doors. The threads of the third race gave precisely the same result; the serum cultures kept in the room gave vigorous growths up to the end of the experiment, while only two colonies developed from the inoculation of the frozen tube. The out-door temperature during the experiment varied from 12° C. to −20° C.

With regard to the behavior of the typhoid bacillus in ice, there is more evidence available. Dr. Carl Seitz (61) noted in 1886 that cultures of this organism in gelatine, bouillon, and milk were not rendered sterile by the continuance of a temperature below 3° C., although the growth on gelatine at the low temperature was very much retarded. Dr. Billings, in this country,(62) described a single experiment in which five cubic centimeters of sterile water were inoculated with the typhoid germ and frozen by the out-door cold. On the next day the frozen mass was thawed, and three gelatine tubes and one agar tube were inoculated with portions of it. Three of the four tubes showed typical growths. Chantemesse and Widal(63) recorded the freezing of bouillon cultures of the same microbe without sterilization. Bashenow(64) stated that typhoid germs survived exposure for thirteen days to a temperature between −8° and −15° C. Janowsky published in 1890 some very extended researches(65) in which he used pure cultures of the typhoid bacillus in bouillon and froze them by means of ice and salt, ice and chloride of calcium or carbon dioxide and ether. He made no quantitative estimations; but bouillon frozen by each of the above methods could still produce growth in Esmarch roll-tubes. Janowsky tried also the effect of successive freezings, using the calcium-chloride mixture. After the culture had solidified, it was left in the freezing mixture for fifteen minutes, then thawed in a water bath at 25°–30° C., a sample taken, and the cycle repeated. This was done three times a day; and during the night the culture was kept at 2°–5° C. After twelve such freezings sterilization had not been accomplished; the development of the frozen bacilli was, however, much retarded. To imitate more closely the conditions in nature, Janowsky placed a bouillon culture and two flasks in which were threads bearing the germ in a dried condition, in a wire cage out of doors. Four sets of experiments were conducted, in three of which periods of seven, ten, and twelve days, respectively, did not suffice for sterilization. In the fourth set of cultures the bouillon tube showed no growth after nineteen days; the minimum temperature during the period had been −17° C. and the maximum 4°, the culture thawing and freezing three times. Finally, among experiments on the typhoid bacillus must be mentioned a remarkable paper by Remlinger,(66) in which he states that he used a culture of B. typhi of such virulence that .5 c.c. would kill a guinea pig in 36–48 hours. He took agar cultures of this germ out of the incubator every two or three hours to immerse them in water, cooled down to 22°–23°, for ten minutes. After ten days of this treatment the cultures had entirely lost their virulence, and after thirty-five days their power of growth as well. The author does not state whether control experiments were made or not.

Even more extensive is the literature with respect to the effect of cold on the cholera vibrio. Koch, the discoverer of the organism, stated that it was not destroyed by a temperature of −10° C. in ten hours.(67) Raptschewski(68) found that cholera germs could endure for a month severe cold, ranging as low as −15° C., but that a temperature of –21° C. was fatal. Von Babes (69) succeeded in keeping a series of agar cultures of the vibrio alive, though exposed to the cold of a Berlin winter (1884–85) ranging as low as –14° C. In the year 1893 no less than eight papers were published dealing with the relation of the cholera germ to cold. Schruff (70) found that a broth culture made from fresh choleraic fæces was not sterilized by eight months' exposure to the winter's cold ranging as low as –12.5° C. Finkelnburg (71) noted that cultures of an old laboratory race were killed out in ten days, while cultures of fresher races were not.

Karschinski (72) stated that a cholera culture with which he worked was sterilized in four days by an average cold of –12.7° C. with a minimum of –17.6° C. Renk (73) froze the germs in sterilized river water at –5° C. to –7° C. and kept the flasks at that temperature, removing one each day for examination. Growth resulting from the melted ice was tested by cover-glass examination and by the Indol reaction. After five days' uninterrupted freezing the cholera germs disappeared, but when the period was broken by the melting of the contents of a flask for analysis and its re-freezing, a little longer period was necessary. When unsterilized river water was inoculated and frozen, the bacteria present fell off from 1,483,000 per centimeter to 62,445 in twenty-four hours, and to 4480 after three days. The cholera germs in this case could not be detected after seventy-two hours, and in one case not after thirty-nine hours. Uffelmann (74) found that cholera germs died out in five days at –15.5° C. and in three days at –24.8° C. Wnukow, (75) on the other hand, stated that gelatine stick cultures of the same microorganism were subjected for forty days to an outdoor temperature between –1° C. and –32° C. without sterilization. Double thawing and freezing also failed to destroy their power of growth. Montefusco (76) tested the pathogenicity of chilled cholera cultures for guinea pigs, and recorded that a temperature of –10° to –15° C. entirely destroyed their virulence in half an hour, while a temperature between 0° and –5° only weakened it. Cultivation at 37.5° soon restored the powers of the germs, but in the chilled and attenuated condition they produced a state of immunity in the animals injected. Abel (77) also mentions experiments in which cholera vibrios frozen in bouillon died out completely in from three to eight days. Kasansky, (78) in 1894, found that cholera cultures withstood for four months the winter's cold at Kasan, where the temperature fell to –31.8° C. One culture gave growth after twenty days of freezing. Some were thawed and refrozen as many as twelve times. After longer exposure, for five months, the cultures gave no growth. Kasansky demonstrated nearly as great a resistance to cold in the case of the vibrios of Finkler-Prior, Miller, Deneke, and Metschnikoff. Finally, some light was thrown on the discordant results of previous observers by the work of Weiss, (79) who inoculated tubes of broth and water from the Spree with cholera cultures and froze them, thawing, sampling, and refreezing the tubes daily. In broth the germs persisted for twenty-one days, but in river water only for five days, the addition of a little broth to the water prolonging the time to eight days. Fresh intestinal contents of a cholera patient showed no vibrios after two or three freezings.[1]

From this long series of experiments it is evident that sterilization of rich cultures of bacteria cannot always be secured by the action of even very extreme cold. Hence the conclusion was drawn that the freezing of water could not be trusted at all to remove its bacterial impurities. There are, however, two objections to this line of reasoning. In the first place, the effect of cold on germs suspended in water may differ materially from its action on similar organisms when in a richly nutrient medium. In the second place, even if sterilization does not result from freezing in cultures containing millions of bacteria, it is conceivable that such a large proportion of the microbes may perish as to render very slender the chance of danger from ice formed under natural conditions. Experiments have shown that easily detected germs like B. prodigiosus can pass through a sand filter when applied to the surface in large numbers under certain conditions; yet a sand filter, in practice, is regarded as an efficient protection. A quantitative determination of the percentage reduction actually effected by freezing is required before drawing conclusions as to the sanitary significance of ice-supply in relation to the public health.

D. QUANTITATIVE STUDIES UPON THE DESTRUCTION OF BACTERIA BY FREEZING AND OTHER LOW TEMPERATURES.

The quantitative studies of Frankland (58) on B. anthracis, of Renk (73) on river-water bacteria, and of Christomonas,(24) on artificial ice, have already been mentioned. Work on the disappearance of bacteria in the freezing of natural water had, however, been undertaken at a much earlier period. Pengra,(80) in 1884, made an actual microscopic count of the organisms present, working with bacteria (species not stated), and other micro-organisms from decomposing meat juice, infusion of hay, and stagnant pools. His freezing was done by the winter's cold, and his figures were obtained by counting the contents of ten drops and taking an average. He found

---

[1] Macfadyen (Lancet, I, 1900, p. 849) has recently exposed cultures of Bacillus typhi, Bacillus coli communis, Bacillus diphtheriæ, Spirillum choleræ asiaticæ, Bacillus proteus vulgaris, Bacillus acidi lactici, Bacillus anthracis (spore bearing), Staphylococcus pyogenes aureus, Bacillus phosphorescens, and Photobacterium balticum in solid and liquid cultures to the temperature of liquid air (−182° C. to −190° C.), for twenty hours without sterilization and without impairing the properties of the organisms in any degree.

Macfadyen and Rowland (Lancet, Vol. I, 1900, p. 1130) treated the same organisms in broth emulsions in fine quill tubes with liquid air for seven days with the same results, except that a slightly delayed growth was noticed in some instances.

in the upper part of the ice 16 bacteria; in the lower part, only partially frozen, 250; in the upper and lower parts of a duplicate unfrozen vessel of water, 160 and 170, respectively. He obtained similar results with three species of Infusoria, and concluded that 90 per cent of the organisms were removed by freezing. His experiments appear, however, to show crystallization effects principally. The first careful work on this subject was done by Fraenkel in Berlin.(81) He collected river water, and after planting samples, froze them artificially at –8° to –12° C., thawing after different periods. In two days 83 per cent of the water bacteria present were killed; in three days 99 per cent; in five days, 90 per cent; in six days, 80 per cent; in six days, in another case, 93 per cent; and in nine days, 99 per cent. The different samples evidently varied greatly. Fraenkel also analyzed the regular Berlin ice-supply, and got results ranging from 21 to 9700 bacteria per cubic centimeter. He concluded that the ice was highly polluted and should not be taken into the system. About the same time Wolffhuegel and Riedel (82) gave an account of some experiments in which flasks of tap-water were kept in the ice-chest without freezing, and showed the following reductions: after one day, from 148 germs per cubic centimeter to 126 and from 150 to 115; after two days, from 123 to 69 and from 158 to 101; after three days, from 123 to 29 and from 156 to 33.

In 1887 Dr. Prudden of New York published the most exhaustive review hitherto attempted of the subject of quantitative reduction, and the first in which specific pathogenic germs were used.(83) His tubes, in the experiments with the latter organisms, were inoculated from pure cultures and frozen at –10° to –1° C., and his results were as follows, the numbers in each case referring to bacteria per cubic centimeter: —

B. prodigiosus. In water, 6300; in ice after 4 days, 2970; after 37 days, 22; after 51 days, 0.

Proteus vulgaris. In water, 8320; in ice after 18 days, 88; 51 days, 0.

Staphylococcus pyogenes aureus. In water, innumerable; in ice after 18 days, 224,598; 20 days, 46,486; 54 days, 34,320; 66 days, 49,280.

Species unnamed. In water, innumerable; in ice after 4 days, 571,450; 11 days, 520,520; 51 days, 183,040; 65 days, 10,978; 77 days, 85,008.

Species unnamed. In water, 800,000; in ice after 7 days, 0.

B. typhi. In water, innumerable; in ice after 11 days, 1,019,403; 27 days, 336,457; 42 days, 89,796; 69 days, 24,276; 77 days, 72,930; 103 days, 7348.

Same. In water, 378,000; in ice after 12 hours, 164,780; after 3 days, 236,676; 5 days, 21,416; 8 days, 76,032.

Dr. Prudden then made certain experiments to determine the effect of alternate freezing and thawing, and obtained the following results. The tubes were here immersed in ice and salt at –20° C.

B. TYPHI.

In water . . . 40,896

Frozen 24 hours	29,780	Refrozen 3 times	90
" 3 days	1,800	" 5 "	0
" 4 "	950	" 6 "	0
" 5 "	2,490	" 6 "	0

B. PRODIGIOSUS.

In water . . . 339,516

Frozen 24 hours	36,410	Refrozen once	2,570
" 30 "	41,580	" 2 times	275
" 48 "	14,440	" 3 "	15
" 96 "	4,850	" 4 "	0

STAPHYLOCOCCUS PYOGENES AUREUS.

In water . . . 111,782

Frozen 15 minutes	52,500		
" 2 hours	21,300		
" 24 "	22,690	Refrozen once	13,495
" 48 "	6,460	" 3 times	110
" 96 "	6,155	" 4 "	0

Dr. Prudden found that, with fresh, active agar cultures of this staphylococcus 49,280 germs remained alive, out of innumerable germs originally present, after sixty days; when cultures from old and dried agar were used, 162,000 germs disappeared entirely after five days. He ultimately drew the following conclusions from these experiments with pathogenic germs: 1. Many bacteria are killed by freezing. 2. The vitality of the original culture affects the number so killed. 3. The number killed varies with the species. 4. The number killed increases as the time of freezing is prolonged. 5. The resistance to cold varies with the individual bacterium. 6. Alternate freezing and thawing is very generally fatal.

Dr. Prudden also froze natural waters with their native bacteria for varying periods, and obtained somewhat similar results. He analyzed 270 samples of New York ice, and found an average of 2033 bacteria per cubic centimeter. The numbers were highest in the upper layers of snow ice and bubbly ice, and in ice cut in the immediate vicinity of Albany, falling off rapidly in ice five or six miles down the river. He concluded that this highly polluted ice probably contained the germs of typhoid fever and should not be taken into the human body.

Later in the same year Bordoni-Uffreduzzi(84) published a paper in which he took issue with Prudden on several points. He contended that the changes of temperature in the latter's experiments were too abrupt, that the resistance of the germs worked with had been weakened by cultivation on artificial media, and that the effect had been abnormally severe on account of the small size of the tubes frozen. He himself analyzed the natural water in one of the municipal basins of Berlin, just before a frost, and then kept a large lump of the ice in a double-walled zinc chest, breaking off samples for analysis every month. He found that about 90 per cent of the bacteria were killed, and thought the duration of the freezing did not make any material difference. His results, of course, varied very widely on account of the unequal distribution of the bacteria in the ice.

Russell(85) a little later made similar experiments at Madison, Wisconsin, in which he found that the ice formed on Lake Mendota contained about 40 per cent of the germs present in the water itself. A report already cited(21) was made by the State Board of Health of Massachusetts in 1889 in which ice from fifty-eight sources was analyzed in comparison with the water on which it had formed. Averaging all results, there were 81 per cent as many bacteria present in the snow ice as in the water, 10 per cent in all the rest of the ice, and only 2 per cent in the clear ice. In the report of the Board for the next year,(86) Mr. Hiram F. Mills noted an isolated but significant experiment in which sterilized tap water was inoculated with the typhoid germ, kept in a bottle surrounded by ice and sampled at intervals. The results were as follows: —

Day	Number of Typhoid Bacilli.	Day	Number of Typhoid Bacilli.
1	6120	15	100
5	3100	20	17
10	490	25	0

Taken altogether, more exact studies confirm the rough estimate of Pengra that some 90 per cent of ordinary water bacteria are eliminated by the process of freezing. As to the percentage reduction of specific pathogenes and, in particular, of the typhoid bacillus, probably the only form of great practical importance, the evidence is very meagre. The only results hitherto, as far as we have been able to discover, which fix quantitatively the effect of cold on this organism, are the three experiments of Dr. Prudden and the single experiment of the biologists of the Massachusetts State Board of Health. These certainly appear to form a slender basis for conclusions relative to the importance of ice-supply as a possible source of typhoid fever.

III. EXPERIMENTS BY THE AUTHORS ON THE EFFECT OF COLD UPON THE BACILLI OF TYPHOID FEVER.

A. EXPERIMENTS ON THE PERCENTAGE REDUCTION OF TYPHOID FEVER BACILLI EFFECTED BY FREEZING FOR DIFFERENT PERIODS OF TIME.

Methods Employed.

The following investigation was undertaken in order to so extend and amplify the work of Prudden as to obtain some idea of the average fatality occurring among typhoid bacilli in ice, and of the special conditions which affect such fatality. Pure cultures alone were used, as it is obvious that figures, to be of much value, must be determined separately for each specific germ. Great pains were taken to preserve, as far as possible, the vigor of the culture used, and new cultures from recent post-mortem examinations were obtained at intervals during the work. Finally, a large number of determinations were made for each set of conditions, in order to obtain average results free from the errors which may beset any individual case.

Our experiments on the percentage reduction effected by freezing were carried on by freezing small tubes of infected water, as only in this way can the conditions of the experiment be rigidly controlled. Ordinary test-tubes, containing about 10 cubic centimeters of sterilized tap water, were inoculated from a two or three day bouillon culture, and duplicate samples were at once planted. The ten tubes of the set under experiment were then placed in a double-walled tin vessel in which they were to be frozen. The inner vessel was a cylinder about 8 inches deep, nearly filled with a mixture of equal parts of glycerine and 95 per cent alcohol; in this solution the tubes were immersed, being supported by a disc perforated with holes to receive them. The solution served to make the lowering of temperature equal and gradual, and also acted as an antiseptic when the tubes broke, which sometimes happened when they contained too much water, or when the temperature went down too rapidly. In the outer vessel, which was jacketed with felt, was placed cracked ice which reduced the temperature of the glycerine-alcohol mixture to about 10°–15° C. in from an hour to an hour and a half. The ice was then replaced by a mixture of ice and salt which completed the freezing in a half or three-quarters of an hour more. The time occupied by the whole process of freezing is recorded in the tabulation of each experiment. The temperature, in the first set of experiments with "Race A," was observed by means of three mercury thermometers inserted in different parts of the liquid, and at the time when the tubes froze the thermometers registered 6°–7° below zero, C. In later experiments the temperature was observed by means of a minimum registering spirit thermometer fastened to the inside of the cover of the inner cylinder, which recorded the temperature of the air just above the liquid in which the tubes were immersed. Partly on this account and probably partly because of its greater quickness of response, this thermometer gave lower records than did the mercury instruments in the first experiments. The readings of the spirit thermometer are given in the tables for each set of tubes.

As soon as the tubes froze, they were removed from the freezer and either thawed at once or kept frozen in an ice-chest for a few hours, or placed in a cold-storage warehouse where they were kept for the longer periods at a temperature one or two degrees below zero, C. After the frozen condition had been maintained for the desired length of time, the contents of the tubes were thawed, shaken up, and sampled, again in duplicate. As a rule the samples taken from the thawed tubes were planted directly, while those made before freezing were diluted, one to ten, with sterilized water. All plates, for these quantitative determinations, were planted with common nutrient agar-agar, containing 1.25 per cent agar, 1.00 per cent Witte's peptone, and .25 per cent salt, and having an acidity equal to 1.50 per cent. As the counts to be made were chiefly comparative, agar was preferred to any other medium, on account of its freedom from liquefaction. The plates were allowed to develop at the room temperature except in certain special cases to be noted later. Those made from the unfrozen water showed their maximum growth in three days and were counted after that interval. Those made from the thawed ice, however, were found to develop more slowly; for them five days was generally found sufficient, although after the longer periods of freezing as much as ten days was sometimes allowed. The plates were finally counted with the aid of a hand lens.

In many of the sets of experiments a control tube was included, which was treated just like the others except that it was not inoculated. Each series of tubes includes two lots of eight or ten each, frozen on two different days.

The cultures were grown in bouillon (containing 1.00 per cent peptone, .25 per cent salt, and 1.00 per cent acid), and were changed twice or three times a week. In the earlier experiments the tubes were inoculated from a culture grown at the room temperature, itself inoculated from one grown at 37.5° C. In the later work the cultures were all kept at the room temperature.

When experiments made on the culture obtained in November, 1898, gave results somewhat different from those given by the culture used in February, it was decided that still a third culture from a different source must be compared with the first two. The results showed that the descendants of these different stocks exhibited slight though constant and persistent differences in their reaction to cold. We have called the cultures derived from these original sources "Races," for physiological races they apparently must be considered.

The first culture used, Race A, was obtained from the Boston City Hospital as a forty-hour-old blood-serum culture on February 23, 1898. Unfortunately, the history and tests applied to this culture in the Hospital were not recorded, beyond the fact that it had been isolated from an autopsy about two weeks previously, by the usual differential methods.

Race B was obtained by the kindness of Dr. M. W. Richardson of the Massachusetts General Hospital in the middle of November, 1898, with the following history. It had been isolated from the spinal canal, in a case of typhoid meningitis. It gave typical reactions in media as follows: bouillon, very motile; litmus milk, no coagulum, slight acid production; sugar-agar, no gas; peptone solution, no indol; gelatine slant stab, typical growth, no liquefaction; arsenic bouillon (Thoinot), no growth; Capaldi-Proskauer sol. No. 1, no growth; potato, no visible growth; tube medium of His, clouding without gas production; typhoid serum, perfect reaction.

Race C was obtained, January 14, 1899, by the courtesy of Dr. Pratt of the Boston City Hospital. It had been isolated, December 30, from the peritoneal cavity in a case of peritonitis following typhoid fever. It gave typical growths on the ordinary media, gelatine, bouillon, and glycerin-agar; it was motile in the hanging drop; it gave no indol and no gas in glucose solution; it was decolorized by the Gram method and reacted to typhoid serum.

Race D was isolated in the laboratory of the City Hospital, March 26, 1899, from the urethra. It was identified by the same tests used for Race C.

RESULTS OBTAINED.

The percentage reductions recorded in the subjoined tables (pp. 492–498), summarized in final form, are as follows: —

PERCENTAGE REDUCTION OBSERVED IN EXPERIMENTS ON THE VIABILITY OF TYPHOID BACILLI IN ICE.

	Race A.	B.	C.	D.
Frozen 15 minutes	59.4	13.8		
" 30 "	63.7			
" 1½ hours		32.2		
" 2 "	73.6			
" 3 "		41.4	99.5	74.8
" 6 "	77.8			97.0
" 12 "		38.6		84.4
" 15 "			98.0	
" 24 "		53.8	82.7	99.0
" 3 days		98.4	99.9	
" 7 "		93.3	99.5	
" 2 weeks	99.8	99.4	99.9	
" 4 "	99.8			
" 8 "	99.8			
" 12 "	99.8			

CONCLUSIONS.

1. Evidently we may reaffirm for the bacillus of typhoid fever the first of Prudden's conclusions as to the various pathogenes with which he worked, namely, that many bacteria are killed by freezing. After two weeks' exposure to the freezing temperature an average of considerably over 99 per cent of the germs perished. Of the 140 tubes inoculated with Races A, B, and C, and frozen for periods of two weeks and over, all but nine showed a reduction of over 99 per cent; and of the nine, all but one showed a reduction of 98 per cent or over. We may safely conclude that less than 1 per cent of the typhoid germs present in water can survive fourteen days of freezing.

2. During the first half-hour of freezing a heavy reduction takes place, amounting, perhaps, to 50 per cent. The tubes exposed for such short times to the unfavorable conditions exhibit a remarkable variability among themselves. In the same set one tube may show no reduction, while its neighbor is rendered almost sterile. Whether these differences are due to the varying physical conditions in the individual tubes, or to variations in the biological character of the loopful of bacteria used for inoculation, is uncertain. From the general harmony of the results obtained it appears that this factor of variability, whatever it may be, is practically eliminated by the averaging of 20 tubes.

After this brief period of sudden but uncertain reduction, the destruction of the germs proceeds pretty regularly as a function of the time. Although the different races vary, there is in each race a steadily increased reduction, with slight variations, as the time of freezing is prolonged. After 14 days, even with the most resistant stock, Race B, the reduction was over 99 per cent. The reduction now proceeds, however, with increasing slowness; the two or three germs per thousand which have survived thus far appear to possess special powers of resistance. Even after 12 weeks few of the individual tubes were rendered sterile. These results appeared so remarkable that special experiments were conducted to test their accuracy, as it was felt that perhaps the few germs developing from the thawed ice might have been introduced from the air, as was obviously the case in some instances. Fifty tubes of Races B and C were therefore frozen for periods of a week and a month; plates were planted from them, with special precautions, and incubated at 37.5°; and the developing colonies were examined individually. The results, as the appended tables show (see p. 492), confirm those of the general investigation. Of the 20 tubes inoculated with Race B and frozen for a month, 10 were sterile; 9 gave one sterile plate, and one with one or two colonies of what proved to be extraneous germs; tube IV. alone gave, on one plate, 7 germs per cubic centimeter, which examination in the hanging drop, and growth on gelatine, and potato, in milk and glucose solution, showed to be the original typhoid culture. So of the 30 tubes of Race C frozen for a week, 17 were sterile; 9 showed contamination, one or two germs per plate; the other four showed 15, 4, 1, and 267 typhoid bacilli per cubic centimeter. These experiments confirm the results of those observers who froze typhoid cultures containing millions of germs without effecting sterilization.

3. Prudden's statement that the number of bacteria killed by freezing varies with the species may be extended. It is evident that within the species B. typhi abdominalis there are races, each having a power of resistance of its own, dependent upon its history within and without the body. A comparison of the tables for the shorter periods of freezing shows clearly that Race C succumbed with much greater readiness to the influence of cold than did Race B; while Races A and D occupied an intermediate position. These differences appear constant through the various sets, so that in each race the progressively increased reduction with more prolonged freezing follows a parallel course. The facts cannot, we think, be attributed to differences in the immediate environment of the germs; such differences do produce their effect, cultivation for a time on agar, for example, causing a decrease in resistance. The last sort of change is, however, temporary and may be quickly reversed by cultivation in bouillon; while the race differences were permanent during the period of experimentation. Correlated with them were certain minor characters; for instance, the weakest race, Race C, grew more slowly than either of the others, and took perceptibly longer to produce a definite clouding in a liquid medium.

RACE A. SERIES I.

Number of Tube.	Average Number Bacteria per c.c.		Reduction per cent.
	Unfrozen Water.	Thawed Ice.	
1	8750	21	99.8
2	910	4	99.5
3	4910	1	99.9+
4	1465	1	99.9
5	900	–	—
6	2475	4	99.8
7	1260	3	99.8
8	1360	10	99.2
9	1535	1	99.9+
10	1030	7	99.3
11	35210	0	100.0
12	22575	3	99.9+
13	53060	1	99.9+
14	8575	–	—
15	94580	–	—
16	116235	1	99.9+
17	140175	–	—
18	95725	4	99.9+
19	4602	3	99.9
20	229950	2	99.9+
Average			99.8

Tubes 1–10, frozen March 2, 1898, in 1½ hours; thawed May 25, after *12 weeks.*

Tubes 11–20, frozen March 4, 1898, in 2 hours; thawed May 27, after *12 weeks.*

RACE A. SERIES II.

Number of Tube.	Average Number Bacteria per c.c.		Reduction per cent.
	Unfrozen Water.	Thawed Ice.	
21	10655	17	99.8
22	7695	42	99.4
23	3170	2	99.9
24	4265	2	99.9
25	90825	1	99.9+
26	79625	2	99.9+
27	5920	6	99.9
28	275	1	99.6
29	5400	1	99.9+
30	2085	3	99.9
31	11480	2	99.9+
32	24637	12	99.9
33	214200	9	99.9+
34	2760	7	99.7
35	10430	113	98.9
36	32110	4	99.9+
37	12757	7	99.9
38	26547	4	99.9+
39	15155	8	99.9
40	19890	1	99.9+
Average			99.8

Tubes 21–30, frozen March 7, 1898, in 2½ hours; thawed May 2, after *8 weeks.*

Tubes 31–40, frozen March 12, 1898, in 2¼ hours; thawed May 7, after *8 weeks.*

RACE A. SERIES III.

Number of Tube.	Average Number Bacteria per c.c.		Reduction per cent.
	Unfrozen Water.	Thawed Ice.	
41	3730	6	99.8
42	7880	5	99.9
43	2810	6	99.8
44	710	7	99.0
45	4470	4	99.9
46	9626	3	99.9+
47	10482	2	99.9+
48	3035	12	99.6
49	2085	11	99.5
50	5710	5	99.9
61	136710	5	99.9+
62	41230	3	99.9+
63	82215	1	99.9+
64	26285	5	99.9
65	22225	1	99.9+
66	19145	3	99.9+
67	Control	Control	—
68	12320	2	99.9+
69	10850	4	99.9+
70	10920	3	99.9+
Average			99.8

Tubes 41–50, frozen March 16, 1898, in 2 hours; thawed April 13, after *4 weeks.*

Tubes 61–70, frozen March 19, 1898, in 1½ hours; thawed April 16, after *4 weeks.*

RACE A. SERIES IV.

Number of Tube.	Average Number Bacteria per c.c.		Reduction per cent.
	Unfrozen Water.	Thawed Ice.	
51	24640	25	99.9
52	49000	10	99.9+
53	48930	30	99.9
54	40450	60	99.8
55	29340	30	99.9
56	282240	65	99.9+
57	44380	110	99.7
58	132300	50	99.9+
59	24185	25	99.9
60	93555	75	99.9
71	55650	–	—
72	Control	Control	—
73	52395	35	99.9
74	9230	70	99.2
75	86870	60	99.9
76	46025	25	99.9
77	1740	25	98.6
78	41825	5	99.9+
79	33155	35	99.9
80	23250	30	99.9
Average			99.8

Tubes 51–60, frozen March 18, 1898, in 1¼ hours; thawed April 1, after *2 weeks.*

Tubes 71–80, frozen March 21, 1898, in 2½ hours; thawed April 4, after *2 weeks.*

RACE A. SERIES V.

Number of Tube.	Average Number Bacteria per c.c.		Reduction per cent.
	Unfrozen Water.	Thawed Ice.	
171	628425	48090	92.3
172	5355	2040	61.9
173	520380	8610	98.3
174	355950	122535	65.6
175	354690	36540	89.7
176	206010	19775	90.4
177	474390	4000	99.0
178	402020	—	—
191	3365	15	99.5
192	3300	40	98.8
193	103320	30	99.9+
194	133875	275	99.8
195	348655	315315	9.6
196	40	70	0.0
197	214200	350	99.8
198	169155	64575	61.8
Average			77.8

Tubes **171–178**, frozen May 9, 1898, in 2 hours; thawed same day, after *6 hours.*

Tubes **191–198**, frozen May 13, 1898, in 2⅓ hours; thawed same day, after *6 hours.*

RACE A. SERIES VI.

Number of Tube.	Average Number Bacteria per c.c.		Reduction per cent.
	Unfrozen Water.	Thawed Ice.	
151	40775	21980	46.1
152	39235	17080	56.5
153	45465	14770	67.5
154	26530	15190	42.7
155	36295	14385	60.4
156	10710	5110	52.3
157	23520	3800	83.8
158	127260	40005	68.6
181	300	15	95.0
182	51030	9660	81.1
183	13265	1410	89.4
184	20475	2955	85.6
185	14595	1145	92.2
186	23415	805	96.6
187	22365	2915	87.0
188	2260	—	—
Average			73.6

Tubes **151–158**, frozen April 30, 1898, in 2¼ hours; thawed, same day, after *2 hours.*

Tubes **181–188**, frozen May 11, 1898, in 2¼ hours; thawed same day, after *2 hours.*

RACE A. SERIES VII.

Number of Tube.	Average Number Bacteria per c.c.		Reduction per cent.
	Unfrozen Water.	Thawed Ice.	
81	1820	990	45.9
82	2795	40	98.6
83	1265	25	98.1
84	820	0	100.0
85	355	15	95.8
86	430	15	96.5
87	2515	2075	17.5
88	1285	0	100.0
89	755	10	98.7
90	165	5	97.0
101	25970	11340	56.3
102	11665	8015	31.3
103	16955	4555	73.1
104	30730	26355	14.2
105	Control	Control	—
106	8750	6510	25.6
107	9205	5525	40.0
108	9345	3380	63.8
109	20090	11410	43.2
110	14315	9170	35.9
Average			63.7

Tubes **81–90**, frozen March 25, 1898, in 1⅔ hours; thawed same day, after *30 minutes.*

Tubes **101–110**, frozen April 9, 1898, in 2 hours; thawed same day, after *30 minutes.*

RACE A. SERIES VIII.

Number of Tube.	Average Number Bacteria per c.c.		Reduction per cent.
	Unfrozen Water.	Thawed Ice.	
121	500220	715	99.9
122	492345	252640	48.7
123	57420	27755	51.7
124	53795	705	98.7
125	Control	Control	—
126	5705	955	83.2
127	124110	7175	94.2
128	77490	9800	87.3
161	33810	17640	47.9
162	276900	275940	.3
163	349020	120960	65.3
164	246645	111930	54.6
165	120775	62050	48.6
166	472500	236880	49.9
167	756550	505575	33.2
168	170100	123795	27.2
Average			59.4

Tubes **121–128**, frozen April 23, 1898, in 1½ hours; thawed same day, after *15 minutes.*

Tubes **161–168**, frozen May 4, 1898, in 1½ hours; thawed same day, after *15 minutes.*

RACE B. SERIES I.

Number of Tube.	Average Number Bacteria per c.c.		Reduction per cent.
	Unfrozen Water.	Thawed Ice.	
71	37275	462	98.8
72	45990	27	99.9
73	41685	189	99.5
74	63210	382	99.4
75	26250	773	97.1
76	34230	599	98.3
77	18800	378	98.0
78	40110	467	98.8
79	42525	613	98.6
80	50295	47	99.9
81	144325	23	99.9+
82	108360	11	99.9+
83	123165	8	99.9+
84	89775	7	99.9+
85	83790	9	99.9+
86	58275	10	99.9+
87	104895	21	99.9+
88	83475	11	99.9+
89	187110	51	99.9+
90	56595	15	99.9+
Average			99.4

Tubes **71–80**, frozen December 16, 1898, in 1⅓ hours; thawed December 30, after *2 weeks*. Minimal temperature, (--14° C).

Tubes **81–90**, frozen December 17, 1898 in 2 hours; thawed December 31, after *2 weeks*. Minimal temperature, (—8° C.).

RACE B. SERIES II.

Number of Tube.	Average Number Bacteria per c.c.		Reduction per cent.
	Unfrozen Water.	Thawed Ice.	
111	52605	3622	93.1
112	88200	1386	98.4
113	95235	4018	95.8
114	63065	1270	98.0
115	31080	1165	96.3
116	43470	1470	96.6
117	47040	896	98.1
118	37065	511	98.6
119	32890	441	98.7
120	54495	2935	94.6
121	10290	2373	76.9
122	54705	4106	92.5
123	69990	1466	97.9
124	21175	2993	85.9
125	45150	—	—
126	61005	4452	92.7
127	61950	3633	94.1
128	114030	17042	85.1
129	90090	8127	91.0
130	6650	805	87.9
Average			93.3

Tubes **111–120**, frozen December 23, 1898, in 2 hours; thawed December 30, after *1 week*. Minimal temperature, (—10° C.).

Tubes **121–130**, frozen December 24, 1898, in 1½ hours; thawed December 31, after *1 week*. Minimal temperature, (—12° C.).

RACE B. SERIES III.

Number of Tube.	Average Number Bacteria per c.c.		Reduction per cent.
	Unfrozen Water.	Thawed Ice.	
91	34965	180	99.5
92	25445	55	99.8
93	28560	60	99.8
94	29085	165	99.4
95	33810	365	98.9
96	32745	25	99.9
97	26880	5705	78.8
98	15855	15	99.9
99	22330	75	99.7
100	90300	30	99.9+
151	2560	2	99.9
152	1595	4	99.7
153	1555	—	—
154	—	—	—
155	225	1	99.6
156	1195	4	99.6
157	95	2	97.9
158	80	1	98.8
159	30	0	100.0
160	25	0	100.0
Average			98.4

Tubes **91–100**, frozen December 20, 1898, in 2 hours; thawed December 23, after *3 days*. Minimal temperature, (—12° C.).

Tubes **151–160**, frozen January 3, 1899, in 2 hours; thawed January 6, after *3 days*. Minimal temperature, (—12° C.).

RACE B. SERIES IV.

Number of Tube.	Average Number Bacteria per c.c.		Reduction per cent.
	Unfrozen Water.	Thawed Ice.	
41	70560	38535	45.4
42	52290	31605	39.5
43	38640	28665	25.8
44	48405	10589	78.1
45	71505	14458	79.8
46	44100	10822	75.4
47	63945	21641	66.2
48	28245	13541	52.1
49	91035	19845	78.3
50	27300	11340	58.3
51	14140	5740	59.4
52	37800	25830	31.7
53	29925	15995	46.6
54	14280	5810	59.3
55	39710	16870	57.5
56	27825	9486	65.9
57	13685	5390	60.6
58	12565	5565	55.7
59	32760	33075	0.0
60	24570	9345	62.0
Average			53.8

Tubes **41–50**, frozen December 1, 1898, in 2 hours; thawed December 2, after *24 hours*. Minimal temperature, (—7° C.).

Tubes **51–60**, frozen December 8, 1898, in 2¼ hours; thawed December 9, after *24 hours*. Minimal temperature, (—10° C.).

RACE B. SERIES V.

Number of Tube.	Average Number Bacteria per c.c.		Reduction per cent.
	Unfrozen Water.	Thawed Ice.	
61	30135	13510	55.2
62	23625	8505	64.0
63	19635	10430	46.9
64	13055	12600	3.4
65	21840	10500	51.9
66	13685	6720	50.9
67	16800	10535	37.3
68	12075	8435	30.1
69	13230	11130	15.9
70	18025	12740	29.3
101	32865	18515	43.7
102	31710	37275	0.0
103	42525	5670	86.7
104	32865	36225	0.0
105	4585	65	98.5
106	22050	9380	57.5
107	5280	184590	0.0
108	5267	206010	0.0
109	15155	0	100.0
110	4585	107740	0.0
Average			38.6

Tubes **61–70**, frozen December 9, 1898, in 2⅓ hours; thawed December 10, after *12 hours*. Minimal temperature, (–6° C.).

Tubes **101–110**, frozen December 21, 1898, in 1½ hours; thawed December 22, after *12 hours*. Minimal temperature, (–8° C.).

RACE B. SERIES VII.

Number of Tube.	Average Number Bacteria per c.c.		Reduction per cent.
	Unfrozen Water.	Thawed Ice.	
1	3515	2080	40.8
2	2180	3000	0.0
3	3535	2620	25.9
4	4455	3105	30.3
5	Control	Control	—
6	4300	4325	0.0
7	4975	3525	29.1
8	3405	3460	0.0
9	4305	5970	0.0
10	4615	3225	30.1
11	7960	6300	20.8
12	16380	14490	11.5
13	7560	6860	9.2
14	19460	21560	0.0
15	12215	10080	17.5
16	21700	15085	30.5
17	7665	8400	0.0
18	13300	11060	16.8
19	10920	11340	0.0
20	10360	14770	0.0
Average			13.8

Tubes **1–10**, frozen November 19, 1898, in 2¼ hours; thawed, same day, after *15 minutes*.

Tubes **11–20**, frozen November 21, 1898, in 1¼ hours; thawed, same day, after *15 minutes*.

RACE B. SERIES VI.

Number of Tube.	Average number Bacteria per c. c.		Reduction per cent.
	Unfrozen Water.	Thawed Ice.	
21	10	200	0.0
22	75	170	0.0
23	190	70	63.2
24	2695	3360	0.0
25	100	250	0.0
26	210	375	0.0
27	1605	1505	6.2
28	180	350	0.0
29	1875	1825	2.7
30	3400	620	81.8
31	22905	12040	47.4
32	32655	8295	74.6
33	18550	6300	66.1
34	22225	6125	72.4
35	13755	4165	69.7
36	15575	3972	74.5
37	15750	7490	52.4
38	15470	3920	74.7
39	19215	5705	70.3
40	9590	2610	72.8
Average			41.4

Tubes **21–30**, frozen November 28, 1898, in 1½ hours; thawed same day, after *3 hours*. Minimal temperature, (–8° C.).

Tubes **31–40**, frozen November 29, 1898, in 1½ hours; thawed same day, after *3 hours*. Minimal temperature, (–8° C.).

RACE C. SERIES I.

Number of Tube.	Average Number Bacteria per c.c.		Reduction per cent.
	Unfrozen Water.	Thawed Ice.	
1	6580	–	—
2	13475	5	99.9+
3	4795	7	99.9
4	9310	4	99.9+
5	10005	5	99.9+
6	10885	2	99.9+
7	6230	102	98.4
8	5215	0	100.0
9	10325	–	—
10	11550	6	99.9+
21	120645	12	99.9+
22	142065	16	99.9+
23	16695	0	100.0
24	0	0	—
25	0	1	—
26	13755	12	99.9
27	378945	1	99.9+
28	101115	0	100.0
29	4370	2	99.9+
30	128520	88	99.9
Average			99.9

Tubes **1–10**, frozen January 16, 1899, in 1⅔ hours; thawed January 30, after *2 weeks*. Minimal temperature, (–13° C.).

Tubes **21–30**, frozen January 18, 1899, in 1⅔ hours; thawed February 1, after *2 weeks*. Minimal temperature, (–10° C.).

Race C. Series II.

Number of Tube.	Average Number Bacteria per c.c.		Reduction per cent.
	Unfrozen Water	Thawed Ice.	
51	1920	2	99.9
52	2675	2	99.9
53	2200	1	99.9+
54	2510	3	99.9
55	2065	33	98.4
56	1605	10	99.4
57	1685	1	99.1
58	835	13	98.4
59	460	15	96.7
60	1820	–	—
71	6580	0	100.0
72	7700	10	99.9
73	2485	1	99.9+
74	6440	1	99.9+
75	5145	3	99.9
76	4130	1	99.9+
77	3920	1	99.9+
78	3080	4	99.9
79	3535	0	100.0
80	540	0	100.0
Average			99.5

Tubes **51–60**, frozen January 23, 1899, in 1½ hours; thawed January 30, after *1 week.* Minimal temperature, (–12° C.).

Tubes **71–80**, frozen January 25, 1899, in 1½ hours; thawed February 1, after *1 week.* Minimal temperature, (–14° C.).

Race C. Series III.

Number of Tube.	Average Number Bacteria per c.c.		Reduction per cent.
	Unfrozen Water.	Thawed Ice.	
11	16765	9	99.9
12	17220	0	100.0
13	14315	2	99.9+
14	900	2	99.8
15	18270	3	99.9+
16	9170	1	99.9+
17	6930	0	100.0
18	7385	0	100.0
19	2925	0	100.0
20	9555	1	99.9+
41	83475	6	99.9+
42	83160	5	99.9+
43	64890	2	99.9+
44	66570	4	99.9+
45	11200	1	99.9+
46	21350	23	99.9
47	2030	3	99.9
48	700	1	99.9
49	185	2	98.9
50	1625	2	99.9
Average			99.9

Tubes **11–20**, frozen January 17, 1899, in 1⅓ hours; thawed January 20, after *3 days.* Minimal temperature, (–13° C.).

Tubes **41–50**, frozen January 20, in 2 hours; thawed January 23, after *3 days.* Minimal temperature, (–10° C.).

Race C. Series IV.

Number of Tube.	Average Number Bacteria per c.c.		Reduction per cent.
	Unfrozen Water.	Thawed Ice.	
61	3335	5	99.9
62	3520	25	99.3
63	195	10	94.9
64	885	55	93.8
65	235	25	89.4
66	215	60	72.1
67	2105	10	99.5
68	555	20	96.4
69	40	20	50.0
70	500	15	97.0
81	1855	85	95.4
82	1830	20	98.9
83	260	55	78.8
84	935	35	96.3
85	110	95	13.6
86	3595	30	99.2
87	4480	35	99.2
88	315	70	77.8
89	50	40	20.0
90	0	40	—
Average			82.7

Tubes **61–70**, frozen January 24, 1899, in 1⅓ hours; thawed January 25, after *24 hours.* Minimal temperature, (–12° C.).

Tubes **81–90**, frozen January 26, 1899, in 1½ hours; thawed January 27, after *24 hours.* Minimal temperature, (–13° C.).

Race C. Series V.

Number of Tube.	Average Number Bacteria per c.c.		Reduction per cent.
	Unfrozen Water.	Thawed Ice.	
91	10710	20	99.8
92	7280	75	99.0
93	9555	90	99.1
94	4645	5	99.9
95	7735	35	99.5
96	1570	355	77.4
97	1325	20	98.5
98	—	—	—
99	6440	590	90.8
100	13090	10	99.9
111	143640	5	99.9+
112	234360	105	99.9+
113	105525	10	99.9+
114	41265	135	99.7
115	11655	5	99.9+
116	36855	20	99.9
117	27195	40	99.9
118	119070	50	99.9+
119	45360	5	99.9+
120	15855	—	—
Average			98.0

Tubes **91–100**, frozen January 27, 1899, in 2 hours; thawed January 28, after *15 hours.* Minimal temperature, (–14° C.).

Tubes **111–120**, frozen February 3, 1899, in 2 hours; thawed February 4, after *15 hours.* Minimal temperature, (–15° C.).

RACE C. SERIES VI.

Number of Tube.	Average Number Bacteria per c.c.		Reduction per cent.
	Unfrozen Water.	Thawed Ice.	
31	350	10	97.1
32	270	0	100.0
33	185	0	100.0
34	90	5	94.5
35	5	0	100.0
36	0	–	—
37	5	0	100.0
38	20	0	100.0
39	5	0	100.0
40	0	0	—
101	172080	1	99.9+
102	61110	9	99.9+
103	56700	1	99.9+
104	40005	4	99.9+
105	16660	0	100.0
106	146475	1	99.9+
107	8855	1	99.9+
108	9345	12	99.9
109	6930	2	99.9+
110	5075	0	100.0
Average			99.5

Tubes **31–40**, frozen January 19, 1899, in 2 hours; thawed same day, after *3 hours.* Minimal temperature, (–8° C.).

Tubes **101–110**, frozen February 2, 1899, in 2 hours; thawed same day, after *3 hours.*

RACE D. SERIES I.

Number of Tube.	Average Number Bacteria per c.c.		Reduction per cent.
	Unfrozen Water.	Thawed Ice.	
1	5355	3080	42.5
2	5915	3265	44.8
3	6090	2465	59.5
4	5670	670	88.2
5	3010	1615	46.3
6	4410	780	82.3
7	3745	365	90.3
8	3290	1000	69.6
9	4375	480	89.0
10	6580	3640	44.7
11	—	—	—
12	2380	95	96.0
13	—	—	—
14	—	—	—
15	7210	65	99.1
16	1855	40	97.8
17	3675	90	97.5
18	—	—	—
19	—	—	—
20	—	—	—
Average			74.8

Tubes **1–10**, frozen April 27, 1899, in 2 hours; thawed same day, after *3 hours.* Minimal temperature, (–16° C.).

Tubes **11–20**, frozen April 28, 1899, in 2 hours; thawed same day, after *3 hours.* Minimal temperature, (–14° C.).

RACE D. SERIES II.

Number of Tube.	Average Number Bacteria per c.c.		Reduction per cent.
	Unfrozen Water.	Thawed Ice	
31	52605	318	99.4
32	53235	5072	90.5
33	77175	52	99.9
34	5565	927	83.3
35	184275	7339	96.0
36	6580	420	93.6
37	1890	—	—
38	62055	6457	89.6
39	3255	87	97.3
40	6020	134	97.8
71	24360	2	99.9+
72	29505	2	99.9+
73	8925	22	99.8
74	2430	0	100.0
75	12810	4	99.9+
76	24355	3	99.9+
77	9450	210	97.8
78	2065	1	99.9+
79	3160	1	99.9+
80	2185	1	99.9+
Average			97.0

Tubes **31–40**, frozen May 1, 1899, in 2 hours; thawed same day, after *6 hours.* Minimal temperature, (–10° C.).

Tubes **71–80**, frozen May 8, 1899, in 2 hours; thawed same day, after *6 hours.* Minimal temperature, (–16° C.)

RACE D. SERIES III.

Number of Tube.	Average Number Bacteria per c.c.		Reduction per cent.
	Unfrozen Water.	Thawed Ice.	
21	3990	15	99.6
22	3675	20	99.5
23	670	15	97.8
24	180	100	44.4
25	595	45	92.4
26	2275	15	99.3
27	180	20	88.9
28	140	25	83.6
29	25	25	0.0
30	240	0	100.0
41	515	33	93.6
42	1575	152	90.3
43	495	39	92.2
44	—	—	—
45	1855	88	95.3
46	2625	409	84.4
47	—	—	—
48	—	—	—
49	7175	511	92.9
50	1025	192	81.3
Average			84.4

Tubes **21–30**, frozen April 28, 1899, in 2 hours: thawed April 29, after *12 hours.* Minimal temperature, (–11° C.).

Tubes **41–50**, frozen May 1, 1899, in 2 hours; thawed May 2, after *12 hours.* Minimal temperature, (–10° C.).

RACE D. SERIES IV.

Number of Tube.	Average Number Bacteria per c.c. Unfrozen Water.	Average Number Bacteria per c.c. Thawed Ice.	Reduction per cent.
51	33915	—	—
52	24570	106	99.6
53	60795	33	99.9
54	15960	35	99.8
55	24805	89	99.6
56	8820	103	98.8
57	6860	6	99.9
58	8960	55	99.4
59	2660	29	98.9
60	130410	199	99.8
61	21735	32	99.9
62	3200	71	97.8
63	5215	5	99.9
64	6160	63	99.0
65	955	10	99.0
66	2085	40	98.1
67	10885	65	99.4
68	250	3	98.8
69	790	34	95.7
70	1150	23	98.0
Average			99.0

Tubes 51–60, frozen May 2, 1899, in 2 hours; thawed May 3, after *24 hours.* Minimal temperature, (—13° C.).
Tubes 61–70, frozen May 3, in 2 hours; thawed May 4, after *24 hours.* Minimal temperature, (—12° C).

RACE B. SPECIAL SERIES.

Number of Tube.	Number Colonies per c.c. Unfrozen Water.		Number Colonies per c.c. Thawed Ice.		
I	56070	83790	0	0	
II	55440	53550	0	0	
III	62370	61110	1	0	
IV	19320	21210	0	7	*
V	42210	29190	0	0	
VI	28980	30030	0	0	
VII	28770	18060	1	0	
VIII	23730	33390	0	1	
IX	46410	42630	1	2	
X	—	7420	0	1	
XI	13720	12180	0	0	
XII	22050	28980	1	0	
XIII	11830	7700	0	0	
XIV	7980	7560	0	0	
XV	7070	6020	1	0	
XVI	6020	4690	0	0	
XVII	5810	4690	0	0	
XVIII	1840	1850	0	1	
XIX	1260	1510	1	0	
XX	3430	4200	0	0	

Tubes I–X, frozen February 10, 1899, in 4 hours; thawed March 10, after *4 weeks.* Minimal temperature, (—10° C.).
Tubes XI–XX, frozen February 15, in 1½ hours; thawed March 15, after *4 weeks.* Minimal temperature, (—10° C.).

* Colonies in ice of Tube IV proved to be typhoid. Colonies in ice in tubes not starred proved to be contaminations.

RACE C. SPECIAL SERIES.

Number of Tube.	Number Colonies per c.c. Unfrozen Water.		Number Colonies per c.c. Thawed Ice.			Number of Tube.	Number Colonies per c.c. Unfrozen Water.		Number Colonies per c.c. Thawed Ice.		
I	4690	5390	0	0		XVI	0	9	0	0	
II	6440	5390	0	1		XVII	21840	17640	0	0	
III	7140	5320	0	1		XVIII	9520	14070	0	0	
IV	9870	12880	18	12	*	XIX	15960	8680	0	0	
V	5560	7210	3	4	*	XX	7910	16170	0	0	
VI	10080	11060	0	1		XXI	25410	30450	3	1	
VII	4060	3710	0	1		XXII	34020	31920	0	–	
VIII	4480	3990	0	2		XXIII	3	0	0	0	
IX	1	1	0	0		XXIV	20790	17640	0	–	
X	1	2	1	–		XXV	107730	103950	272	262	*
XI	147420	148050	0	–		XXVI	380	560	0	1	
XII	2	0	0	0		XXVII	0	0	0	0	
XIII	63630	71190	0	0		XXVIII	330	210	0	1	*
XIV	57960	48510	0	0		XXIX	150	280	0	0	
XV	87570	86940	1	0		XXX	1330	1440	0	0	

Tubes I–X, frozen February 17, 1899, in 3 hours; XI–XX, February 23, in 2 hours; XXI–XXX, March 3, in 1¾ hours; thawed after *1 week* in each case. Minimal temperature, —10° C.

* Colonies in ice proved to be typhoid. Colonies in ice in tubes not starred proved to be contaminations.

B. EXPERIMENTS ON THE EFFECT OF ALTERNATE FREEZING AND THAWING UPON THE BACILLI OF TYPHOID FEVER.

Dr. Prudden, as we have seen, considered intermittent more fatal than uninterrupted freezing, and, indeed, succeeded in one case in entirely sterilizing a tube inoculated with B. typhi by this method. Our four series of experiments on this subject were conducted by freezing tubes in the freezer as described in the previous section. The tubes of Series I, Race A, were frozen daily for five days and allowed to thaw each time after about eighteen hours, samples being planted after each thawing. Those of Series I, Race B, were frozen three times, on alternate days, remaining frozen for twenty-four hours each time and kept below 2° for the rest of the time. The two series in Race D were treated like the tubes frozen for three hours and six hours in the last section, except that instead of remaining frozen they were thawed and refrozen once and twice respectively during that time.

The results of these experiments with the results of simple freezing directly comparable are as follows: —

RACE A.

	Reduction.
Frozen once in one day	96.1
Frozen twice in two days	98.9
Frozen three times in three days	99.5
Frozen four times in four days	99.8

RACE B.

Kept frozen for three days (see previous section, Race B, Series III)	98.4
Frozen twice in four days	99.6
Kept frozen for seven days (see previous section, Race B, Series II)	93.3
Frozen three times in six days	99.8

RACE D.

Kept frozen for three hours (see previous section, Race D, Series I)	74.8
Refrozen once in three hours	97.4
Kept frozen for six hours (see previous section, Race D, Series II)	97.0
Refrozen twice in six hours	99.5

CONCLUSION. Thawing and refreezing are somewhat more fatal than simple freezing in its effect on the typhoid bacillus. Four successive freezings and thawings do not, however, suffice to kill off the most resistant bacilli.

RACE A. SERIES I.

Number of Tube.	Average before Freezing.	After One Freezing.		After Two Freezings.		After Three Freezings.		After Four Freezings.	
		Average.	Reduction per cent.	Average.	Reduction per cent.	Average.	Reduction per cent.	Average.	Reduction per cent.
91	49910	—	—	—	—	—	—	—	—
92	22785	175	99.3	6	99.9	1	99.9	3	99.9
94	348390	26320	92.5	2495	99.3	644	99.9	147	99.9
95	308385	1735	99.5	171	99.9	59	99.9	2	99.9
96	167580	535	99.7	6	99.9	2	99.9	2	99.9
97	277515	40	99.9	1	99.9	3	99.9	2	99.9
98	50820	745	98.5	290	99.4	200	99.6	120	99.8
99	600	180	70.0	4	99.3	1	99.8	—	—
100	34090	190	99.4	55	99.9	16	99.9	8	99.9
111	76895	380	99.5	80	99.9	22	99.9	20	99.9
112	23875	685	97.1	355	98.5	33	99.9	13	99.9
113	29750	—	—	—	—	—	—	—	—
114	38290	265	99.3	40	99.9	3	99.9	0	100.0
115	31500	1785	94.3	1232	96.1	416	98.7	427	98.6
116	46585	75	99.8	3	99.9	23	99.9	3	99.9
117	21	17	—	15	—	2	—	2	—
118	48335	4450	90.8	3895	91.9	2440	95.0	—	—
119	38430	155	99.6	11	99.9	2	99.9	2	99.9
120	25200	215	99.1	14	99.9	2	99.9	3	99.9
	Averages		96.1		98.9		99.5		99.8

Tubes 91–100, frozen March 28, 1898; thawed and sampled and refrozen, on each of the four days succeeding. Tubes remained frozen 18 hours each time.

Tubes 111–120, treated in same manner week of April 11, 1898.

RACE B. SERIES I.

Number of Tube.	Average before Freezing.	After One Freezing.		After Two Freezings.		After Three Freezings.	
		Average.	Reduction per cent.	Average.	Reduction per cent.	Average.	Reduction per cent.
1	46950	420	99.1	67	99.9	38	99.9
2	22260	155	99.3	24	99.9	23	99.9
3	12810	315	97.5	21	99.8	19	99.9
4	12145	215	98.2	52	99.6	29	99.8
5	10640	20	99.8	10	99.9	7	99.9
6	8715	120	98.6	10	99.9	5	99.9
7	7945	80	99.0	13	99.8	9	99.9
8	4190	65	98.4	13	99.7	7	99.8
9	2520	85	96.6	9	99.6	4	99.8
10	2450	95	96.1	7	99.7	1	99.9+
11	115290	775	99.3	280	99.8	161	99.9
12	142695	1980	98.6	1008	99.3	356	99.8
13	183385	315	99.8	96	99.9	85	99.9+
14	74970	1140	98.5	595	99.2	354	99.5
15	138915	480	99.7	276	99.8	116	99.9
16	227745	11865	94.8	5733	97.5	458	99.8
17	104265	670	99.4	198	99.8	129	99.9
18	107730	1250	98.8	403	99.6	269	99.8
19	163485	650	99.6	139	99.9	65	99.9+
20	120015	390	99.7	171	99.9	75	99.9
	Averages		98.5		99.6		99.8

Tubes 1–10, frozen April 10, 1899; kept frozen for 24 hours, and below 2° for 24 hours more; refrozen April 12 and April 14. Samples planted before each freezing and April 15.

Tubes 11–20, treated in same way, April 17, and following days.

Race D. Series I.

Number of Tube.	Average Number Bacteria per c.c.		Reduction per cent.
	Unfrozen Water.	Thawed Ice.	
101	78435	147	99.8
102	76230	451	99.4
103	1765	23	98.7
104	2730	47	98.3
105	275	15	94.5
106	7735	26	99.7
107	1120	49	95.6
108	11690	134	98.9
109	6895	235	96.6
110	—	—	—
131	—	—	—
132	—	—	—
133	3500	175	95.0
134	—	—	—
135	29190	77	99.7
136	20160	371	98.2
137	6055	192	96.8
138	5710	388	93.2
139	—	—	—
140	3885	144	96.3
Average			97.4

Tubes **101–110**, frozen May 5, 1899; thawed and refrozen in *3 hours*. Minimal temperature, (−13° C.).
Tubes **131–140**, frozen May 13, 1899; thawed and refrozen in *3 hours*. Minimal temperature, (−19° C.).

Race D. Series II.

Number of Tube.	Average Number Bacteria per c.c.		Reduction per cent.
	Unfrozen Water.	Thawed Ice.	
111	34020	71	99.8
112	59090	152	99.7
113	13230	7	99.9
114	32525	274	99.2
115	1545	9	99.4
116	4270	29	99.3
117	2095	1	99.9+
118	6685	5	99.9
119	5250	68	98.7
120	13685	210	98.5
121	—	—	—
122	—	—	—
123	203175	3	99.9+
124	40005	1	99.9+
125	56070	2	99.9+
126	170100	297	99.8
127	—	—	—
128	—	—	—
129	—	—	—
130	925	1	99.9
Average			99.5

Tubes **111–120**, frozen May 9, 1899; thawed and refrozen twice in next *6 hours*. Minimal temperature, (−14° C.).
Tubes **121–130**, frozen May 10, 1899; thawed and refrozen twice in next *6 hours*. Minimal temperature, (−10° C.).

C. EXPERIMENTS ON THE EFFECT OF TEMPERATURES SLIGHTLY ABOVE THE FREEZING-POINT UPON TYPHOID BACILLI IN WATER.

In these experiments sterilized test tubes were inoculated with pure cultures as in all the preceding work. Afterward they were treated in one of three ways, — either placed in an incubator at the room temperature, 20° C., or in an ice-chest ranging from 8°–12°, or cooled in the freezer to a point just above freezing. This last was effected by filling the outer chamber with ice without salt.

In the three sets of tubes treated by the last method at 1°, the duration of exposure and the reduction were as follows: Race A in two hours was reduced 47.8 per cent; Race B in one and one-half hours was reduced 32.9 per cent; Race C in three hours was reduced 80.1 per cent. The reductions for the same races actually frozen for the nearest corresponding periods, were 73.6 per cent, 41.4 per cent, and 99.5 per cent, respectively. Each race maintains its relative position of resistance. The reduction in the chilled water is very nearly as great as in the ice; and the difference is only what the temperature difference might be expected to produce. Evidently there is nothing mysterious about the act of freezing, no mechanical crushing of bacteria; the process of destruction is continuous above and below the freezing-point, depending upon the two main factors of time and temperature.

Series II and III of Races B and C cover longer periods of time and higher temperatures. Half of the tubes in each series were kept at 10° and half at 20°, but no marked differences appeared as the result of these two modes of treatment, and the two sets are averaged together in each series. The tubes were kept in these experiments for two weeks, one-half of them being sampled on the second and the seventh day, the others on the third day and the fourteenth. The tubes were, of course, protected from the action of light.

	Race B.		Race C.	
	Reduction per cent.		Reduction per cent.	
Time.	Series II.	Series III.	Series II.	Series III.
1 day	92.2	78.7	88.4	71.0
3 days	99.3	86.7	90.4	83.3
7 days	99.9	99.3	94.1	89.6
14 days	99.9	98.8	99.9	99.9

It will be noted that with each race the second series shows a greater reduction than the third. The explanation for this lies in the fact that these experiments were carried on some time after the regular experiments on freezing their respective races. During the intervening period the germs had been grown on agar, and the first new series of experiments with each race showed an extraordinary reduction, over 99 per cent in a day, etc. The results of this series have not been tabulated. The second series of each race, Series II above, showed more moderate, but still high reductions; while by the time the third series was inoculated, a week later, the cultures, by cultivation in bouillon, had regained their normal condition.

The tubes inoculated with Race D were kept for twenty-four hours only, samples being planted after 3, 6, 12, and 24 hours. Series I was kept at 20° and Series II at 10°.

	After 3 hours.	6 hours.	12 hours.	24 hours.
Series I (20°)	70.8	72.6	85.7	88.4
Series II (10°)	63.1	74.0	87.4	95.5

Conclusions. From these experiments it appears that typhoid fever bacilli behave in water much as they do in ice. A large proportion of them are killed by a few minutes' exposure to the unfavorable conditions; during the next few hours the reduction proceeds *pari passu* with the duration of the experiment; while a few germs persist for some time.

The results differ from those obtained by actual freezing in two respects. We have seen that freezing for short periods produced varying and uncertain results, while ice over twenty-four hours old showed a constant reduction of over 90 per cent. The tubes of water which were not frozen remained subject to this uncertainty for a much longer period. Inspection of the tables will show that individual tubes contained sometimes half of their original germ content after a week, or four-fifths of it after three days. On the other hand, complete sterilization ensued more often than in the frozen tubes.

A second characteristic of the viability of the germs in water is the fact, closely allied to the first, that an increase seems sometimes to occur. The successive samplings of the same tube show in certain instances a slight multiplication.

The reduction in water at 10° does not seem to be any greater than at 20°.

RACE A. SERIES I.

Number of Tube.	Average Number Bacteria per c.c.		Reduction per cent.
	Unfrozen Water.	Thawed Ice.	
131	140490	51450	63.4
132	505	10	98.0
133	10640	11410	0.0
134	12390	6965	43.8
135	31465	165	99.5
136	273105	87885	67.8
137	17745	9870	44.4
138	112770	63000	44.1
141	254205	105840	58.4
142	157815	92610	41.3
143	72135	42490	41.1
145	302715	302715	0.0
146	141750	45990	67.6
147	17360	21735	0.0
Average			47.8

Tubes **131–138**, cooled down to 1° C. in 1¼ hours, April 25, 1898. Kept at that temperature for ½ hour more.

Tubes **141–147**, cooled down to 1° C. in 1¼ hours, April 29, 1898. Kept at that temperature for ½ hour more.

RACE B. SERIES I.

Number of Tube.	Average Number Bacteria per c.c.		Reduction per cent.
	Unfrozen Water.	Thawed Ice.	
131	1946	1690	13.2
132	1610	1001	37.8
133	1848	1165	37.0
134	1571	1183	24.7
135	1379	1155	16.1
136	1291	1505	0.0
137	1232	1438	0.0
138	874	962	0.0
139	892	1473	0.0
140	1022	1051	0.0
141	4095	5	99.9
142	260	50	80.8
143	205	90	56.1
144	270	55	79.6
145	40	5	87.5
146	215	145	32.6
147	290	275	5.2
148	225	140	37.8
149	215	120	44.2
150	80	75	6.3
Average			32.9

Tubes **131–140**, cooled down to 0°, without freezing, and kept at that temperature for 1½ hours. Date, December 29, 1898.

Tubes **141–150**, cooled down to 0°, without freezing, and kept at that temperature for 1½ hours. Date, January 2, 1899.

RACE C. SERIES I.

Number of Tube.	Average Number Bacteria per c.c.		Reduction per cent.
	Unfrozen Water.	Thawed Ice.	
121	55125	14910	73.0
122	244755	217350	11.2
123	66465	11045	83.4
124	62685	59010	5.9
125	211050	32760	84.5
126	269955	75915	71.9
127	103005	7385	92.8
128	105840	8085	92.4
129	67725	20685	69.5
130	23100	4725	79.5
131	139860	9660	93.1
132	76545	3675	95.2
133	58275	6580	88.7
134	219135	23205	89.4
135	82530	3675	95.6
136	84105	3150	96.3
137	1290	0	100.0
138	38850	2105	94.6
139	30030	860	97.1
140	5530	640	88.4
Average			80.1

Tubes **121–130**, cooled down to 0° in ½ hour, February 6, 1899; kept at that temperature (not frozen) for three hours.

Tubes **131–140**, cooled down to 0° in ½ hour, February 7, 1899; kept at that temperature (not frozen) for 3 hours.

RACE B. SERIES II.

Number of Tube.	Average after Inoculation.	After One Day.		After Three Days.		After Seven Days.		After Fourteen Days.	
		Average.	Reduction per cent.	Average.	Reduction per cent.	Average.	Reduction per cent.	Average.	Reduction per cent.
201	232155	20	99.9+			2	99.9+		
202	93870	6755	92.8			0	100.0		
203	104895	4515	95.7			0	100.0		
204	9345	1180	87.4			0	100.0		
205	72135	60	99.9			1	99.9+		
206	51660			0	100.0			0	100.0
207	56070			1837	96.3			3	99.9+
208	1515			0	100.0			0	100.0
209	216405			2972	98.8			21	99.9+
210	Control			Con	trol			Con	trol
211	11025	0	100.0			1	99.9+		
212	17885	5075	71.6			51	99.7		
213	20790	90	99.6			0	100.0		
214	10420	30	99.7			0	100.0		
215	81270	2020	75.2			73	99.9		
216	10640			1	99.9+			1	99.9+
217	825			0	100.0			8	99.0
218	170			1	99.4			0	100.0
219	22330			5	99.9+			0	100.0
220	74340			623	99.2			3	99.9+
	Averages		92.2		99.3		99.9		99.9

Tubes 201–210, inoculated March 17, 1899; kept in ice-chest at about 10° C.
Tubes 210–220, inoculated March 17, 1899; kept in room at about 20° C.

RACE B. SERIES III.

Number of Tube.	Average after Inoculation.	After One Day.		After Three Days.		After Seven Days.		After Fourteen Days.	
		Average.	Reduction per cent.	Average.	Reduction per cent.	Average.	Reduction per cent.	Average.	Reduction per cent.
221	113400	21630	80.8			2467	97.8		
222	74340	385	99.5			3	99.9+		
223	74340	13405	82.0			1043	98.6		
224	48510	7840	83.8			1043	97.8		
225	137025	2425	98.2			0	100.0		
226	17535			1389	92.1			0	100.0
227	103635			40446	61.0			6835	93.4
228	74655			27405	63.3			1603	97.9
229	25200			2520	90.0			28	99.9
230	85050			7465	91.2			112	99.9
231	34650	5355				30	99.9		
232	18795	6930				5	99.9+		
233	7320	1205				39	99.5		
234	5145	3420				9	99.8		
235	5565	1195				16	99.7		
236	5075		84.5	22	99.6			1	99.9+
237	10535		63.1	312	97.0			2	99.9+
238	4340		83.5	28	99.3			3	99.9
239	17955		33.5	4284	76.1			486	97.3
240	6090		78.5	173	97.2			3	99.9+
	Averages		78.7		86.7		99.3		98.8

Tubes 221–230, inoculated March 24, 1899; kept in ice-chest at about 10° C.
Tubes 231–240, inoculated March 24, 1899; kept in room at about 20° C.

RACE C. SERIES II.

Number of Tube.	Average after Inoculation.	After One Day.		After Three Days.		After Seven Days.		After Fourteen Days.	
		Average.	Reduction per cent.	Average.	Reduction per cent.	Average.	Reduction. per cent.	Average.	Reduction per cent.
141	68985	1596	97.7			30	99.9+		
142	81270	10206	87.4			1043	98.7		
143	143640	1141	99.2			56	99.9+		
144	198450	107730	45.7			125956	36.5		
145	132300	1883	98.6			38	99.9+		
146	198450			13041	93.4			196	99.9
147	210735			2142	99.0			30	99.9+
148	80325			238	99.9+			2	99.9+
149	82215			479	99.9			2	99.9+
150	79065			228	99.9+			0	100.0
151	51345	1176	97.7			2	99.9+		
152	66780	14238	78.7			501	99.2		
153	349650	11970	96.9			128	99.9+		
154	73395	7	99.9+			0	100.0		
155	230580	40761	82.3			8347	96.4		
156	168210			135229	19.6			54	99.9+
157	41265			1400	96.6			22	99.9
158	17395			16	99.9			1	99.9+
159	83790			3402	95.9			5	99.9+
160	120015			42	99.9+			3	99.9+
	Averages		88.4		90.4		94.1		99.9

Tubes **141–150**, inoculated March 20, 1899; kept in ice-chest at 10°.
Tubes **151–160**, inoculated March 20, 1899; kept in room at about 20° C.

RACE C. SERIES III.

Number of Tube.	Average after Inoculation.	After One Day.		After Three Days.		After Seven Days.		After Fourteen Days.	
		Average.	Reduction per cent.	Average.	Reduction per cent.	Average.	Reduction per cent.	Average.	Reduction per cent.
161	10535	15	99.9			1	99.9+		
162	26985	5	99.9+			1	99.9+		
163	44205	30660	30.6			242	99.5		
164	5705	30	99.4			0	100.0		
165	340	230	32.4						
166	41685			7497	82.0			119	99.7
167	1080			45	95.8			1	99.9
168	24465			2709	88.9.			14	99.9
169	15330			15876	0.0				
170	Control			Control				Con	trol
171	420	40	90.5			0	100.0		
172	1205	805	33.2			1	99.9		
173	305	0	100.0			1	99.7		
174	19740	9275	53.0			609	96.9		
175	1065	310	70.9			2	99.8		
176	3255			46	98.6			1	99.9+
177	4105			271	93.4			2	99.9+
178	1725			1	99.9			0	100.0
179	620			0	100.0			2	99.7
180	17850			1596	91.1			48	99.7
	Averages		71.0		83.3		89.6		99.9

Tubes **161–170**, inoculated March 27, 1899; kept in ice-chest at 10°.
Tubes **171–180**, inoculated March 27, 1899; kept in room at about 20° C.

Race D. Series I.

Number of Tube.	Average after Inoculation.	After Three Hours.		After Six Hours.		After Twelve Hours.		After Twenty-four Hours.	
		Average.	Reduction per cent.	Average.	Reduction per cent.	Average.	Reduction per cent.	Average.	Reduction per cent.
141	2590	30	98.8	0	100.0	5	99.8	5	99.8
142	5670	25	99.5	20	99.6	0	100.0	5	99.9
143	2315	5	99.8	225	90.3	0	100.0	10	99.6
144	3185	140	95.6	90	97.2	20	99.4	0	100.0
145	15	10	33.3	15	0.0	10	33.3	—	—
146	340	70	79.4	60	82.4	10	97.1	25	92.6
147	745	30	96.0	210	71.8	5	99.3	10	98.7
148	50	35	30.0	0	100.0	0	100.0	20	60.0
149	45	30	33.3	50	0.0	0	100.0	5	88.9
150	230	40	82.6	5	97.8	5	97.8	5	97.8
151	52920	22890	56.7	18690	64.7	7969	84.9	770	98.5
152	8680	6300	27.4	3780	56.5	1704	80.1	483	94.4
153	68670	28350	58.7	26885	60.8	21168	69.2	20097	70.7
154	43155	715	98.3	385	99.1	252	99.4	119	99.7
155	6650	1025	84.6	380	94.3	273	95.9	158	97.6
156	41895	7000	83.3	7105	83.0	5323	87.3	4410	89.5
157	74025	12355	83.3	14700	80.1	11056	85.1	6647	91.0
158	53235	7980	85.0	13125	75.3	14647	72.5	5386	89.9
159	23205	6090	73.8	9695	58.2	8064	65.2	10206	56.0
160	3255	2745	16.0	1925	40.9	1669	48.7	1480	54.5
	Averages		70.8		72.6		85.7		88.4

Tubes **141–150**, inoculated May 11, 1899. Kept at room temperature.
Tubes **151–160**, inoculated May 15, 1899. Kept at room temperature.

Race D. Series II.

Number of Tube.	Average after Inoculation.	After Three Hours.		After Six Hours.		After Twelve Hours.		After Twenty-four Hours.	
		Average.	Reduction per cent.	Average.	Reduction per cent.	Average.	Reduction per cent.	Average.	Reduction per cent.
161	27615	7455	73.9	5810	79.0	—	—	6268	77.3
162	291060	47145	83.8	21000	92.8	—	—	3895	98.7
163	200340	11235	43.9	205	99.9	—	—	1	99.9+
164	208530	24045	88.5	10500	95.0	—	—	5261	97.5
165	178605	1860	99.0	355	99.8	—	—	21	99.9+
166	54810	7000	87.2	—	—	—	—	—	—
167	106785	11655	89.1	2275	97.9	—	—	1543	86.4
168	212625	4130	98.1	1385	99.4	—	—	2001	99.1
169	25095	1960	92.2	745	97.1	—	—	529	97.9
170	2660	145	94.5	35	98.7	—	—	129	95.2
171	236250	95445	59.6	78435	66.8	25578	89.2	3643	98.5
172	240975	120330	50.1	144585	40.0	45360	81.3	20128	91.8
173	199395	98595	50.6	41840	79.0	16065	91.9	196	99.9
174	299565	150255	49.8	156200	47.8	29578	90.1	5691	98.1
175	179550	104895	41.6	54180	69.8	9670	94.4	2992	98.3
176	107730	64260	40.4	72265	32.9	17010	84.2	2396	97.8
177	133235	69930	47.5	81900	38.5	17671	86.7	7140	94.6
178	141750	89515	36.8	35700	74.8	20790	85.3	1101	99.2
179	211680	226800	0.0	158760	25.0	56891	73.1	31468	85.1
180	47565	30765	35.3	8610	71.9	1141	97.6	288	99.4
	Averages		63.1		74.0		87.4		95.5

Tubes **161–170**, inoculated May 17, 1899. Kept in ice-chest at 10°.
Tubes **171–180**, inoculated May 19, 1899. Kept in ice-chest at 10°.

D. EXPERIMENTS ON THE VIABILITY OF TYPHOID FEVER BACILLI IN EARTH AT VARIOUS TEMPERATURES.

These experiments were carried on in order to compare the conditions affecting a reduction of the number of typhoid bacilli in soil, with those operating on them in water and ice. The general method pursued was the same, the inoculation of numerous small portions of a sterile medium with a pure culture of the micro-organism. In each series of experiments about one hundred grains of sifted clayey soil were sterilized by baking for sixteen hours, on two successive days. The whole of the earth was then inoculated by mixing with it a bouillon culture two or three days old, of B. typhi, Race B; and an even distribution was accomplished by stirring and kneading with a spatula. The earth, having been dried by the previous baking, absorbed the bouillon culture without becoming visibly damp. Fifty portions of the inoculated earth of one gram each were then weighed out and placed in fifty sterile empty test-tubes. Of these fifty portions, ten were at once mixed with sterile water and two check plates made from each flask. The remaining forty tubes were carried to the cold storage warehouse or kept at the room temperature, as the case might be, in either condition being protected from the action of light. After one day, three days, one week, and two weeks, ten tubes were removed and planted. In every case the entire gram of earth was mixed with ten, one hundred or nine hundred cubic centimeters of sterile water; and two check plates were made from the dilution.

The inoculation, weighing and tubing of the earth, were conducted in a glass chamber some three feet square, with a sliding door raised only sufficiently to admit the arms of the operator. Control plates were made from four portions of the earth before inoculation, the portions of a gram apiece being tubed and planted exactly like the regular tubes. The following were the results per gram: —

COLONIES PER GRAM.

1		2		3		4	
14	1	0	3	0	0	360	0

The tubes of the first three series were kept at the cold storage warehouse during the period of the experiment, at 0° C. Those of the fourth series were kept at the room temperature. The summarized average results of these four series are as follows: —

Typhoid Bacilli in Earth. Average Number per Gram.

Series		After Inoculation.	After 1 day.	3 days.	7 days.	14 days.
Series I	0°	180776	4635	705	25	9
II	0°	4846855	95017	1395	525	588
III	0°	7778595	324588	4656	1304	1160
IV	20°	4673683	2565	450	95	92

Two more series of experiments with earth were carried out to throw light on the part played by dryness in the reduction manifest in the first experiments. In these latter researches the sets of fifty tubes were inoculated just as before, and ten of them were planted at once. The remaining forty were divided into two portions. The gram of earth in each of twenty of the tubes was moistened by the addition of about one-third cubic centimeter of sterilized tap water; while the earth in the other twenty tubes was left in its comparatively dry condition. The tubes were all kept at the room temperature. Thus a comparison may be drawn as to the viability of the germ in damp and in dry earth. The results were as follows:—

Typhoid Bacilli in Dry and Damp Earth. Average Number per Gram.

Series	After Inoculation.		After 1 day.	3 days.	7 days.	14 days.
Series V	939115	Dry	2070	50	2	47
		Damp	225	7010	1295	8
VI	1198260	Dry	566	71	12	4
		Damp	1699110	—	—	29587

Conclusions. 1. The typhoid bacilli in dry earth behave just as in water and in ice. They die out, rapidly at first, and their numbers are progressively reduced as the treatment is prolonged. A fraction of one per cent persists for some time.

2. Cold alone does not materially affect the reduction of typhoid germs in dry earth.

3. In moist earth, although the main phenomena are the same, the destruction of the bacteria is much less rapid. With the liberal food supply introduced with the bouillon in these experiments, they appear sometimes to hold their own entirely.

TYPHOID BACILLI IN EARTH.

Series I.

Number of Tube.	February 13, 1899.	
	Bacteria per gram.	
1	233000	243000
2	217000	—
3	114000	112000
4	123000	120000
5	504000	207000
6	107000	126000
7	178000	141000
8	157000	153000
	Average	180776

Number of Tube.	February 14, 1899.	
	Bacteria per gram.	
11	5400	1800
12	4500	4500
13	7200	1800
14	6300	4500
15	2700	3600
16	900	5400
17	1800	13500
18	8100	9900
19	3600	1800
20	2700	2700
	Average	4635

Number of Tube.	February 16, 1899.	
	Bacteria per gram.	
21	900	600
22	1000	900
23	900	200
24	600	400
25	900	1600
26	900	400
27	400	700
28	300	400
29	900	800
30	400	700
	Average	705

Number of Tube.	February 20, 1899.	
	Bacteria per gram.	
31	30	10
32	10	0
33	90	50
34	0	10
35	0	0
36	30	0
37	0	80
38	30	70
39	10	40
	Average	25

Number of Tube.	February 27, 1899.	
	Bacteria per gram.	
41	20	0
42	30	40
43	10	0
44	0	0
45	20	0
46	20	0
47	0	0
48	0	30
49	0	0
50	0	0
	Average	9

Tubes kept at 0° C.

SERIES II.

Number of Tube.	February 20, 1899.		Number of Tube.	February 21, 1899.	
	Bacteria per gram.			Bacteria per gram.	
1	4932900	5896800	**11**	130500	175500
2	5046300	4649400	**12**	103500	—
3	5216400	4876200	**13**	119700	81900
4	2286900	4706100	**14**	55800	70200
5	5953500	7030800	**15**	54000	51300
6	2570400	3628800	**16**	102600	—
7	5159700	4309200	**17**	41400	37800
8	6860700	5443200	**18**	117900	140400
9	3686500	4989600	**19**	114300	115200
			20	126900	74700
	Average	4846855		*Average*	95017

Number of Tube.	February 23, 1899.		Number of Tube.	February 27, 1899.		Number of Tube.	March 6, 1899.	
	Bacteria per gram.			Bacteria per gram.			Bacteria per gram.	
21	1200	1300	**31**	30	110	**41**	340	400
22	1400	1900	**32**	210	310	**42**	160	110
23	700	1700	**33**	60	240	**43**	1770	750
24	500	1200	**34**	660	470	**44**	1070	1690
25	1100	800	**35**	110	90	**45**	160	200
26	300	700	**36**	240	290	**46**	150	900
27	2200	4000	**37**	310	500	**47**	120	800
28	2600	3100	**38**	820	210	**48**	360	430
29	1100	700	**39**	190	240			
30	400	1000	**40**	2890	2620			
	Average	1395		*Average*	525		*Average*	588

Kept at 0° C.

SERIES III.

Number of Tube.	February 24, 1899.		Number of Tube.	February 25, 1899.	
	Bacteria per gram.			Bacteria per gram.	
1	8541900	7144200	**11**	466200	522900
2	6747300	7200900	**12**	529200	229500
3	7314300	6066900	**13**	409500	621100
4	10432800	10092600	**14**	415800	371700
5	7711200	6917400	**15**	270900	258300
6	6860700	7597800	**16**	289800	216900
7	7881300	8278200	**17**	573300	346500
8	8731800	6577200	**18**	144900	171100
9	6463800	7711200	**19**	5400	3600
10	9695700	7994700			
	Average	7778595		*Average*	324588

Number of Tube.	February 27, 1899.		Number of Tube.	March 3, 1899.		Number of Tube.	March 10, 1899.	
	Bacteria per gram.			Bacteria per gram.			Bacteria per gram.	
21	1600	1400	**31**	220	370	**41**	1710	420
22	2400	1500	**32**	380	250	**42**	1390	350
23	6900	7300	**33**	3710	370	**43**	1770	—
24	1500	900	**34**	310	—	**44**	—	—
25	1600	2600	**35**	3290	240	**45**	2870	2150
26	4000	3600	**36**	5530	2310	**46**	660	420
27	1900	1600	**37**	930	270	**47**	160	210
28	10500	25200	**38**	690	480	**48**	1510	40
			39	1020	4410	**49**	1360	1450
			40	190	140	**50**	2420	1220
	Average	4656		*Average*	1304		*Average*	1160

Kept at 0° C.

SERIES IV.

Number of Tube.	February 28, 1899.		Number of Tube.	March 1, 1899.	
	Bacteria per gram.			Bacteria per gram.	
1	4139100	6010200	**11**	10800	4500
2	3742200	4876200	**12**	2700	900
3	3798900	2721600	**13**	2700	1800
4	3685500	—	**14**	900	900
5	5896800	7144200	**15**	1800	2700
6	5216400	5556600	**16**	900	900
7	4025700	3628800	**17**	1800	900
			18	900	0
			19	5400	7200
			20	1800	1800
	Average	4673683		*Average*	2565

Number of Tube.	March 3, 1899.		Number of Tube.	March 7, 1899.		Number of Tube.	March 14, 1899.	
	Bacteria per gram.			Bacteria per gram.			Bacteria per gram.	
21	900	1800	**31**	20	10	**41**	10	0
22	900	0	**32**	20	30	**42**	140	380
23	0	900	**33**	60	20	**43**	20	170
24	1800	0	**34**	30	10	**44**	130	110
25	900	0	**35**	90	10	**45**	350	30
26	0	0	**36**	690	60	**46**	160	60
27	0	0	**37**	340	100	**47**	40	0
28	0	900	**38**	120	20	**48**	40	20
29	0	0	**39**	250	0	**49**	190	0
30	900	0	**40**	10	10			
	Average	450		*Average*	95		*Average*	92

Kept at 20° C.

Series V.

AFTER INOCULATION.

Number of Tube.	March 15, 1899.	
	Bacteria per gram.	
1	1045800	863100
2	1140300	989100
3	1663200	1499400
4	573300	938700
5	592200	686700
6	1297800	863100
7	1348200	—
8	1004400	919800
9	1026900	636300
10	888300	875700
	Average	939115

DAMP EARTH.

	Number of Tube.	Bacteria per gram.		Averages.
March 16	**11**	0	0	
	12	900	0	
	13	0	900	
	14	0	0	
				225
March 18	**21**	0	0	
	22	100	0	
	23	21100	25100	
	24	8400	15000	
	25	400	0	7010
March 22	**31**	220	180	
	32	10	0	
	33	3360	6580	
	34	0	10	
	35	—	—	1295
March 29	**41**	40	40	
	42	0	0	
	43	0	0	
	44	0	0	
	45	0	0	8

DRY EARTH.

	Number of Tube.	Bacteria per gram.		Averages.
March 16	**16**	900	900	
	17	9000	1800	
	18	0	2700	
	19	900	3600	
	20	0	900	2070
March 18	**26**	200	0	
	27	100	0	
	28	100	100	
	29	0	0	
	30	0	0	50
March 22	**36**	0	0	
	37	0	0	
	38	0	0	
	39	10	0	
	40	0	10	2
March 29	**46**	10	30	
	47	260	100	
	48	20	0	
	49	20	0	
	50	10	20	47

Series VI.

AFTER INOCULATION.

Number of Tube.	March 29, 1899. Bacteria per gram.	
1	1455300	1379700
2	1682100	1455300
3	1152900	1228500
4	1083600	825300
5	926100	1152900
6	1304100	1020600
7	1152900	1568700
8	1115100	1266300
9	926100	1096200
10	1398600	774900
	Average	1198260

DAMP EARTH. DRY EARTH.

	Number of Tube.	Bacteria per gram.		Averages.		Number of Tube.	Bacteria per gram.		Averages.
March 30	**11**	1341900	1266300		March 30	**16**	200	300	
	12	2060100	1719900			**17**	600	4200	
	13	1436400	1247400			**18**	50	130	
	14	2891700	3364200			**19**	60	40	
	15	963900	699300	1699110		**20**	60	20	566
April 1	**21**				April 1	**26**	30	40	
	22					**27**	320	20	
	23					**28**	70	40	
	24					**29**	—	—	
	25			—		**30**	0	50	71
April 5	**31**				April 5	**36**	0	0	
	32					**37**	10	10	
	33					**38**	10	30	
	34					**39**	10	10	
	35			—		**40**	0	40	12
April 12	**41**	33300	41400		April 12	**46**	10	12	
	42	900	0			**47**	6	5	
	43	1800	1800			**48**	—	—	
	44	88200	69300			**49**	1	2	
				29587		**50**	1	4	4

E. EXPERIMENTS ON THE EFFECTS OF SEDIMENTATION AND CRYSTALLIZATION DURING THE FREEZING OF TYPHOID FEVER BACILLI IN WATER.

In the experiments under Section I, the reduction effected represented simply the death-rate among the bacteria due to the adverse conditions. All the bacteria in the unfrozen water which did not perish must, from the nature of the case, be present in the thawed ice. In nature, however, the conditions are widely different. Ice is formed immediately over and in immediate contact with a large body of water. In the water, before and during the process of freezing, the bacteria, being particles somewhat heavier than water, continually tend to settle out from the region where ice is to form and fall gradually to the bottom. And when the ice formation actually takes place, a still more powerful force comes into play. In the process of crystallization there is a strong tendency to throw out all substances other than the pure compound chiefly concerned. If, then, soluble chemical compounds, other than hydrogen monoxide are excluded to a large extent when water freezes, this must be still more the case with suspended particles like the bacteria.

These *a priori* conclusions are strengthened by the work of Pengra and of the Massachusetts State Board of Health as well as by common scientific knowledge. To test them more carefully with respect to Bacillus typhi abdominalis and Bacillus coli the following experiments were made. A new wine-cask, of about ten gallons capacity, was allowed to stand full of water for a few days in order to remove any extractives present. Four pet-cocks were then screwed in, on opposite sides of the cask, two about four inches from the top and the others an inch or so from the bottom. The whole cask was jacketed with felt so that when placed at a low temperature it would freeze from above down and not from the sides inward. It was then filled with water, at about the boiling-point, drawn from an ordinary water-heater. This water was then allowed to stand for twenty-four hours, when it was found cool and still very nearly sterile, containing three or four germs per cubic centimeter. The barrel of water was then inoculated by pouring into it a bouillon culture of the germ used, the common colon bacillus in the first four experiments, the typhoid bacillus, Race B, in the last two. During the course of the experiments no sterilization was attempted beyond that partially effected by the boiling water. After adding the culture and stirring with a sterile rod, samples were taken from the four pet-cocks and planted. The covered cask was then set aside in the room or placed on a broad sill just outside the window of the laboratory, where it was exposed to the winter's cold. After twenty-four hours of this treatment a thin sheet of ice a quarter to half an inch thick was found covering the surface. Samples were again taken from the upper cocks just under the ice, and from the lower cocks at the bottom of the barrel, and portions of the ice were also planted, being melted in sterile bottles, after washing with the water produced by their own melting, according to the usual technique.

CONCLUSIONS. 1. These experiments indicate that sedimentation does not produce marked or constant effects on colon and typhoid bacilli in water during as short a period as twenty-four hours.

2. On the other hand, the experiments show that ice formed on the surface of a quiet body of water contains only about ten per cent of the bacteria present in the water just below. This difference is probably due to the physical exclusion by the process of crystallization and not to any germicidal action, as the temperature of the ice can only differ from that of the adjacent water by a very slight amount. There are two distinct forces at work, — the low temperature, killing out germs in the ice and water nearly equally, and the crystallizing process extruding germs from the ice into the water below.

REDUCTION OF BACTERIA BY SEDIMENTATION.

B. COLI. SERIES I.

Bacteria per c.c. in samples taken from top and bottom of cask.

	December 29, 1898.				Averages.
Top	60270	51870	19320	18900	42590
Bottom	3570	3680	4550	4310	4028
	December 30, 1898.				
Top	11200	15610	12390	10095	12324
Bottom	51030	44730	13020	13580	30590
	December 31, 1898.				
Top	7070	6860	5110	5495	6132
Bottom	51870	8120	5845	40740	26640

Kept in room.

SERIES II.

	January 3, 1899.				Averages.
Top	120960	110880	114660	101430	114480
Bottom	114030	97650	103320	85050	100012
	January 4, 1899.				
Top	54180	42840	60910	56070	53500
Bottom	52920	47880	60270	62160	56050

Put outdoors. Temperature –5° to –10° C. Surface did not freeze.

REDUCTION OF BACTERIA BY SEDIMENTATION AND BY FORMATION OF ICE ON FREE SURFACE.

B. Coli. Series III.

		January 9, 1899.				Averages.
	Top	28560	21630	23100	20370	23415
	Bottom	25620	10010	32760	12180	20142
		January 10, 1899.				
	Ice	370	250	550	670	460
Water	Top	4620	4900	—	—	4380
	Bottom	4410	10360	7490	7700	7490

Put outside. Temperature –1° C. ¼ inch ice formed.

Series IV.

		January 11, 1899.				Averages.
	Top	69930	62370	45990	76860	63787
	Bottom	57330	61110	68670	77490	66150
		January 12, 1899.				
	Ice	1240	950	1890	780	1215
Water	Top	15720	11760	9870	8410	11440
	Bottom	8820	10920	13090	13020	11462

Put outside. Temperature, –15° C. ¼ inch ice formed.

B. Typhi. Series I.

		January 18, 1899.				Averages.
	Top	147420	226800	198450	204120	194197
	Bottom	247590	211680	245700	153090	214515
		January 19, 1899.				
	Ice	21840	28350	27090	23940	25305
Water	Top	234360	194670	147420	145530	180495
	Bottom	209790	176660	232470	181440	200090

Put outside. ⅛ inch ice formed.

Series II.

		January 19, 1899.				Averages.
	Top	202230	198450	156870	171990	182385
	Bottom	154980	218610	302400	254520	232627
		January 20, 1899.				
	Ice	68040	75600	18480	17430	44887
Water	Top	270270	404460	578340	319960	393257
	Bottom	307180	257040	386820	238140	297295

Put outside. ¼ inch ice formed.

IV. DEDUCTIONS FROM THE EXPERIMENTS CONCERNING ICE AS A VEHICLE OF INFECTIOUS DISEASE, WITH SPECIAL REFERENCE TO THE PROBLEMS OF ICE-SUPPLY AND THE PUBLIC HEALTH.

Reviewing the several series of experiments described in detail above, and keeping carefully in mind the conditions under which natural ice is formed, cut, harvested, stored, delivered, and finally consumed, as well as those pertaining to the manufacture, distribution, and consumption of artificial ice, certain conclusions appear to be justified concerning ice as a vehicle of disease; and these conclusions are, on the whole, decidedly reassuring.

The conditions which tend naturally to purify polluted waters, are now well understood. Light, cold and poor food-supply are antiseptic or disinfectant agents of considerable power; hostile infusoria may devour the living germs of infectious disease; the chemical composition of the water may be unfavorable to their survival; and gravity may cause them to settle to the bottom, where they may soon perish for want of air. The main factor determining the reduction of germs in water is, however, the *time,* — the time during which these and other forces are left to act. Epidemiology shows clearly that disease follows best a direct, quick transfer of infectious material from patient to susceptible victim; and, if storage of water for some months could be insured, many sanitarians would consider such storage a sufficient purification.

In ice we have this condition realized, — a forced storage of at least weeks and at best of many months. At the same time the other effective conditions are also heightened. It is no wonder, then, that our experiments show a reduction of over 99 per cent in typhoid bacilli frozen; and we may be sure that in nature the destruction would exceed, rather than fall short of, such a limit.

This reduction obtains in tubes which are frozen solid, where there is no chance for mechanical exclusion. In natural ice there is another purifying influence. Of the germs remaining in the water at the time of freezing, 90 per cent are thrown out by the physical phenomena of that process. This reduction is separate from, and supplementary to, the disinfecting action of the cold. Accordingly, when both factors work together, it is obvious that only one out of a thousand typhoid germs present in a polluted stream has a chance of surviving in the ice.

Under natural conditions the pathogenic germs present in the most highly polluted stream are comparatively few. Of these few, one-tenth of one per cent may be present in ice derived therefrom. But even these scattered individuals are weakened by their sojourn under unfavorable conditions, so that, as we have seen, they require nearly twice as long for their development as do the normal germs, and these few and weakened germs very likely could not produce many, if any, cases of typhoid fever, for vitality and virulence in disease germs are probably closely related.

With artificial ice the case is somewhat different, for such ice is made from water frozen solid, and is, as a rule, quickly consumed. Artificial ice, if made from pure water, should be above reproach; but if it be made from water that is impure it may contain the germs of infectious disease; and inasmuch as artificial ice is used quickly after its manufacture, the possibility of purification by time is excluded, and such ice might therefore conceivably be a menace to the public health.

With natural ice, as long as absolute sterilization is not effected, there must always remain a certain element of doubt, as in the use of sand filters, alluded to above, or in the practice of room-disinfection after contagious diseases. The thickness of a layer of ice is often artificially increased by cutting holes in it and flooding that already formed with the water of the pond. In such a case the effects of crystallization are excluded, as in the laboratory tubes. Ice thus formed might be cut at once, and served within a week or two; and in such an exceptional case we cannot say that sufficient of the virus might not persist to excite the malady. Yet such an instance must be very exceptional; and the general result of human experience, the absence of epidemics of typhoid fever traced conclusively to ice, the fact that cities like New York, and Lowell and Lawrence in Massachusetts, have used the ice of polluted streams, and have yet maintained low death-rates from typhoid fever, all tend to support the conclusion at which we have arrived, namely, that natural ice can very rarely be a vehicle of typhoid fever.

PART II.

STATISTICAL STUDIES ON THE SEASONAL PREVALENCE OF TYPHOID FEVER IN VARIOUS COUNTRIES AND ITS RELATION TO SEASONAL TEMPERATURE.

I. A REVIEW OF THE LITERATURE ON THE SEASONAL PREVALENCE OF TYPHOID FEVER.

The variations in the prevalence of typhoid fever with the changing seasons was one of the characteristics of that remarkable disease which struck the very earliest observers. Elisha Bartlett, in 1842,(87) wrote of it as follows: "It is not settled whether typhoid fever occurs, with any degree of uniformity, more frequently in one season of the year than in another. . . . I am sure, however, that, as a general rule, its annual prevalence is greatest in the autumn. In New England it is not unfrequently called the autumnal or fall fever."

Dr. Flint, in 1855,(88) pointed out as one of the points of distinction between typhus and typhoid fever that while the former is unaffected by season, the latter "manifests a predilection for the autumnal months, although it is by no means restricted in its occurrence to the latter." Griesinger, a little later,(89) noted that in middle Europe and North America the majority of cases as well as the epidemic outbreaks occurred most abundantly in autumn, and that the winter typhoid stood next in relative intensity, followed by that of summer, while the fewest cases occurred in the spring. He quoted Lombard as authority for the fact that in Geneva the month of October shows seven times as many typhoid cases as the month of March. In 1860, Dr. Tweedie(90) published a table of the admissions of the different forms of continued fever into the London Fever Hospital for ten years and brought out an interesting contrast between typhoid and typhus fevers. His monthly figures for typhoid were as follows:—

J	F	M	A	M	J	J	A	S	O	N	D
113	85	77	60	79	119	157	233	260	253	223	161

By quarters the difference between the two forms of fever, then just beginning to be clearly distinguished, was shown very markedly.

QUARTERLY ADMISSIONS.

	Typhus Fever.	Typhoid Fever.
First Quarter	1074	275
Second "	1088	258
Third "	725	650
Fourth "	619	637

Dr. Tweedie concluded that "typhus is most prevalent in spring, and the least so in autumn, while enteric fever is least prevalent in spring, and most prevalent in autumn." In the same year, Hirsch, in the first edition of the "*Historisch-geographischen Pathologie*," (92) gave an extensive résumé of current opinion on the subject. He quoted statistics to show that of 519 typhoid epidemics, 168 occurred in autumn, 140 in winter, 132 in summer, and only 79 in spring. He also printed a table of typhoid cases at the hospitals of Lausanne and Geneva, in Lowell and Nassau, and of typhoid deaths in the canton of Geneva and the State of Massachusetts, showing an autumn maximum and a spring minimum in every case. Summer occupied the second place except at Nassau and the canton of Geneva. As to the weather influences controlling this prevalence of the disease he quoted very conflicting opinions. While Drake and Huss attributed the autumnal fever largely to the summer temperature, Davidson and Lombard considered a relatively high humidity as of prime significance. Thomson maintained that both factors were of importance, and Seitz, Cless, and Franque denied any effect of meteorological conditions. Another review of the seasonal variations of typhoid fever was published by Murchison in 1862.(93) He quoted nine English and continental authorities as recording the autumnal maximum, and added a table of the admissions into the London Fever Hospital which showed a steady rise from April to October. Fiedler, in the same year,(94) noted that typhoid fever in Dresden was much more abundant in the second half of the year than in the first, and gave the following table of typhoid admissions for eleven years.

ADMISSIONS TO THE DRESDEN HOSPITAL, 1850–60.

J	F	M	A	M	J	J	A	S	O	N	D
123	76	114	82	83	105	113	191	189	132	143	146

The first systematic attempt to show a relation between typhoid fever and definite meteorological conditions was made by Haller in 1860.(91) This author maintained that the seasonal curve of typhoid corresponded to that of air pressure, and that the greatest prevalence was at periods of low temperature, noting, in that connection, the alleged fact that typhoid fever does not occur autochthonously south of the isotherm of 22° C. Haller's results, however, were not confirmed by other observers; and a new theory as to the ætiology of typhoid fever soon took almost complete possession of the field. This was the famous ground-water theory of Pettenkofer and the Munich school. As applied to typhoid fever this theory was launched by Ludwig Buhl in the first article of the first number of the "*Zeitschrift für Biologie.*"(95) The author dealt with eight hundred and ninety-nine typhoid deaths in a Munich hospital during the period 1855–64, and compared, by the graphic method, the monthly and yearly variations with the changes in temperature, precipitation, and ground-water level. The seasonal curve showed a maximum between December and March, culminating in February, and a minimum in August and October. These monthly variations, and the fluctuations from year to year, did not correspond to the temperature or the precipitation, but did show a certain inverse relation to the height of the ground water.

Seidel(96) analyzed the figures given by Buhl in a more elaborate manner. He compared for each of the one hundred and eight months, from 1856 to 1864, the typhoid cases and the ground-water level, using in each case the difference between the value for the individual month and the average value for that month during the whole period. In 73.5 cases an excess of typhoid fever corresponded with an excessive fall of the ground water, and in 34.5 cases the reverse relation obtained. Seidel estimated the probability of this preponderance being due to chance alone as one to thirty-six thousand. His monthly averages for morbidity are as follows: —

TYPHOID CASES. MUNICH HOSPITAL. AVERAGE, 1856–64.

J	F	M	A	M	J	J	A	S	O	N	D
14.1	12.0	6.9	5.2	5.2	6.0	4.8	6.8	4.2	7.6	12.2	13.1

In the next year, Seidel(97) analyzed Buhl's figures in relation to the monthly precipitation, again excluding any difference of season per se, by using only the differences between the value for a month and the average value for the same month during the nine years considered. He demonstrated a certain inverse relation between an excess of precipitation and the prevalence of typhoid fever just as in the case of the variation in ground-water level, and considered both factors as of importance. Of the fifty-six months in which precipitation and ground-water level varied in the same sense, forty-six showed a variation of typhoid morbidity in the opposite sense.

The studies relating to the cases at the Munich Hospital were extended to the whole city by Pettenkofer in 1868.(99) He reproduced a chart prepared by F. Wagus, which gives by months the typhoid mortality for the whole city from 1850 to 1867 in comparison with the precipitation and the height of the ground water. The seasonal distribution of the disease coincided with that observed at the hospital, the average number of typhoid deaths for the whole city being as follows: —

J	F	M	A	M	J	J	A	S	O	N	D
33.5	36.8	31.8	23.1	17.6	15.2	15.8	16.7	16.1	15.0	19.0	28.5

A long series of polemical papers on the relation of typhoid, and more particularly of cholera, to the ground water was contributed by Pettenkofer to the "*Archiv für Hygiene*" and the "*Zeitschrift für Biologie*," and his conclusions were finally summarized in pamphlet form.(115), (118) For a time the theories of the Munich school appeared to hold the field. Virchow (101) studied the typhoid mortality in Berlin for the period 1854–71, and concluded that there was a striking inverse relation with the ground-water level. Virchow and Guttstadt (114) published curves for Berlin from 1883 to 1885, which showed a direct relation to the temperature and an inverse relation to the ground-water level. Finally, a most elaborate presentation of the facts was made by Dr. Soyka in 1887.(117) Like his confrères, this author rested his case in large part on the variations in the intensity of the disease and the height of the ground water from year to year; but he also treated of the seasonal variations at some length. Although his table of the monthly distribution of the disease in seventeen cities, reproduced below, showed an autumnal maximum in all but four cases, he considered that these exceptions, Augsburg, Munich, Prague, and Vienna, proved the temperature relation to be an indirect one.

PERCENTAGE MONTHLY DISTRIBUTION OF TYPHOID.

After Soyka.

Place.	Period.	Total No.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
Berlin	1854–85	16660	6.5	6.0	5.4	5.9	5.9	5.6	8.1	11.0	12.6	13.5	10.6	8.2
Neufchatel Lausanne	1835–52	933	8.6	5.2	5.5	2.6	4.0	6.1	7.7	10.1	13.4	17.0	9.8	9.4
Breslau	1863–78	2521	7.7	7.5	7.5	6.4	6.1	7.4	8.5	9.6	11.3	10.5	8.7	8.0
Frankfort-a-M.	1853–85	1496	7.9	7.1	6.2	5.6	5.8	6.2	8.4	10.6	11.8	12.1	9.0	8.7
Hanover	1874–85	397	7.6	5.1	6.4	6.1	10.0	7.4	5.0	9.1	12.1	13.6	9.6	8.0
Basel	1826–73	2213	8.6	6.4	6.1	5.4	7.2	7.6	8.4	9.1	10.7	10.7	10.6	8.7
Paris	1867–78	4152	6.2	5.7	4.6	4.9	4.2	4.9	6.9	12.3	13.4	12.5	13.5	10.3
Augsburg	1856–78	1092	11.0	6.7	8.1	5.3	5.1	5.2	7.3	8.9	9.7	9.7	10.6	10.8
Bern	1871–80	340	9.7	6.8	7.3	9.1	6.1	7.3	5.8	6.1	10.0	7.9	12.9	10.6
Munich	1851–85	7530	11.5	11.9	11.2	9.0	7.5	6.9	6.4	6.5	6.3	5.8	6.9	9.6
Prague	1873–84	998	10.5	9.9	10.2	8.5	9.3	9.6	9.8	6.9	7.1	5.0	6.2	6.8
Vienna	1871–85	4992	8.2	7.1	11.8	10.1	9.9	8.0	8.1	7.5	7.3	7.3	6.9	7.7
Basel *	1875–85	3599	10.3	7.1	8.0	6.7	8.0	8.2	10.1	14.8	8.6	6.9	5.7	4.9
Leipzig *	1851–65	1052	9.4	5.7	5.1	4.3	3.8	6.0	9.3	13.0	12.9	13.2	9.4	7.2
Copenhagen *	1842–58	3198	6.1	3.3	3.2	2.8	3.1	5.0	7.9	13.3	18.3	16.4	9.9	10.2
Bremen *	1872–84	1648	7.6	7.0	6.6	4.8	4.9	4.7	8.1	9.6	13.8	16.3	9.1	7.0
Chemnitz *	1838–82	1455	6.2	6.4	7.3	5.2	5.1	6.9	7.4	9.3	13.2	13.2	10.8	8.0
Christiania *	1845–64	4550	11.3	7.3	6.1	4.3	4.0	3.3	6.1	8.8	8.6	9.6	16.8	13.2

* Morbidity. Other figures refer to mortality.

Soyka finally plotted the typhoid fever and ground-water level in Berlin, Frankfort, Bremen, and Munich, and obtained quite regular complementary curves. His final conclusion was that "the rhythm of typhus abdominalis is in general the inverted rhythm of the ground-water fluctuations."

Unfortunately other researches did not harmonize with these results. Socin at Basle (100) and Fodor at Buda-Pesth (110) found quite different relations between typhoid and ground-water level. Later examinations of the yearly variations, even in Munich, failed to show the correspondence noted prior to 1881. Most potent of all, however, in overthrowing the ground-water theory was the gradual substitution of zymotic for miasmatic conceptions of disease which robbed it of any rational, ætiological basis.

The only plausible explanation of the connection between ground water and typhoid fever, on the basis of the germ theory, had been furnished by Liebermeister,(98) who suggested in 1860 that the phenomena observed by Buhl might simply be due to the concentration of soil impurities in wells at the time of low water and their transmission in unusually large doses to those who drank therefrom. A simple modification of Liebermeister's idea, including a recognition of the fact that a well in use drains a wider area when the ground water is low and is thus liable to pollution from more distant sources, has been strongly advocated in this country by Dr. H. B. Baker of Michigan. As early as 1878 Dr. Baker (108) published curves showing the seasonal distribution of the more important diseases, and pointed out the contrast between such diseases as bronchitis, pneumonia, and croup which culminate in the winter and the fevers and diarrhœal diseases which attain a maximum in the hot months. His curves showed a slight rise in October for typhoid fever and much more marked rises for the classes of "Typho-malarial," "Remittent," and "Intermittent" fevers, the figures for which in absolute value greatly exceeded those for the former disease. Similar tables were published in the succeeding annual reports; and in 1882 it was stated that "more than the average per cent of weekly reports stated the presence of typhoid fever in months when the average daily temperature, the average daily range of temperature, the absolute humidity of the atmosphere, the monthly and the average daily range of the barometer and the average daily pressure of the atmosphere were greater than the average for the year; and less than the average per cent of reports stated the presence of typhoid fever in months when these conditions were less than the average for the year." These curves and conclusions have been repeated year by year in each annual report, the only change being the gradual increase of "typhoid fever" relative to the "typho-malarial" and "remittent" fevers with improvement in diagnosis. In 1884, Dr. Baker(113) treated typhoid fever in more detail, comparing the seasonal variations of the disease for five years with the height of the ground water in Michigan and showing that the disease increased quite regularly with the number of inches of earth above the water in the wells. He concluded that "in summer when vegetation is active and not decaying, a lowering of the water is uniformly followed by increased prevalence of typhoid fever; with the advent of colder weather there is a rise in the water level which is uniformly followed by a decreased prevalence of the fever; that this decrease continues through the winter and spring even though the level of the well water is lowered, provided the surface of the earth is deeply frozen; that on the contrary high-water level in wells in winter and spring coincident with ground not thoroughly frozen is followed by increased prevalence of the fever."

The relation to ground water was again studied in the Report of the Michigan State Board of Health for 1888 (p. lv.), and 1890 (p. 247); and in the Report for 1894 (p. 300) and succeeding reports, new diagrams were published and the following conclusions were added: "The evidence is conclusive that there is a necessary relation between the low water in wells and the sickness from typhoid fever. The fluctuations in the sickness from typhoid fever and the depth of the water in wells are nearly coincident throughout the several months. The maximum of sickness and the minimum of water are coincident in October." Finally, in 1897, Dr. Baker(128) printed a new diagram exhibiting the curves of typhoid fever and ground water for fourteen years, and suggested in support of his explanation of the inverse relation shown that another factor of less universal importance than the pollution of wells by distant privies might be the infection of air, food, and drink by germs blown from the surface of the ground, which must be dryer and more exposed to such action when the ground water is low.

Dr. Baker's theory regarding the pollution of wells at times of low water seems quite insufficient to account for such a universal phenomenon as the autumnal maximum of typhoid fever, even with the additional suggestion as to air contagion. Well water is by no means the most important source of the disease; and even as to wells the theory does not take all the facts into account. Other observers have attempted to trace with some success an almost exactly opposite relation between typhoid fever and excessive precipitation. Dr. F. H. Welch,(111) for example, who noted that the maximum of typhoid fever occurred in the last quarter of the year in Malta and in Bermuda, in the latter half of the year at Gibraltar, during the autumnal months, — from March to May, — at the Cape of Good Hope, and in the warm season in India, finally concluded that "the great natural assistant (in the spread of the disease) is the rainfall in giving moisture for growth and putrefaction, in causing water circulation on the surface and in the subsoil, in its mechanical removal of material from drains and hidden receptacles."

Whatever the explanation, it seems to be proven that at Munich in the period studied by Pettenkofer and his followers a real relation did exist between ground-water level and typhoid. In no other case, as far as we are aware, has another factor been excluded which normally varies inversely with the ground-water level and which does bear a plausible relation to the distribution of the typhoid germ. This factor is the temperature; and the seasonal curve in many places, Michigan, for example, and Berlin, can be more satisfactorily explained by a direct relation to the temperature than by an inverse relation to the ground-water level. The first author forcibly to call attention to the importance of the temperature factor was Murchison. In the second edition of his work on the continued fevers,(102) he gave a table of the monthly admissions into the London Fever Hospital from 1848 to 1870, of which the totals were as follows: —

J	F	M	A	M	J	J	A	S	O	N	D
433	306	318	209	232	335	434	721	803	839	819	539

Murchison pointed out that a "great increase of enteric fever in the autumn months was observed in each of the twenty-three years, with one noteworthy exception (1860)." He also noted that the autumnal increase did not subside immediately on the advent of winter, and concluded that "it would seem as if the cause of the disease were only exaggerated or called into action by the protracted heat of summer and autumn, and that it required the protracted cold of winter and spring to impair its activity or to destroy it."

He quoted numerous observers, Todd and Burne in England, Stewart in Scotland, Lombard and Rilliet and Barthez in Switzerland, Piedvache, de Claubry and Druher in France, Forget and Quincke in Germany, and Bartlett, Wood, and Flint in the United States, as recording the autumnal character of the disease. Finally he added, "Not only does enteric fever increase in autumn, but it has been found to be unusually prevalent after summers remarkable for their dryness and high temperature, and to be unusually rare in summers and autumns which are cold and wet." The references to the early authorities quoted by Murchison will be found in his elaborate bibliography.

Liebermeister also had a clear conception of the possible effect of temperature upon the prevalence of typhoid fever. In his article on typhoid fever in Ziemssen's Cyclopedia,(103) he plotted the monthly deaths in Berlin and hospital admissions in London and Basle, compared with curves of the monthly variations in temperature, and commented on the results as follows: "The general bearing of these curves is evident. The curves representing the frequency of typhoid correspond to the curves of average temperature, only with this difference. The different points of the typhoid curve follow those of the temperature curve by an interval of some months. The minimum of temperature falls in January, that of typhoid in February or April; the maximum of temperature falls in July, that of typhoid in September and October. It appears, therefore, that the development and spread of typhoid fever is favored by the high summer temperature and checked by the low winter temperature. The interval of two or three months between the temperature and the typhoid curves correspond to the time which is necessary for the changes of temperature to penetrate to the places where the typhoid poison is elaborated, for the development of the poison without the human body, for the period of incubation, and for the time between the commencement of the attack and that of the patient's admission to the hospital, or that of his death."

Cousot,(104) in France, about the same time, noted that the month of October always showed a maximum of typhoid, that the intensity then diminished till spring, and that the summer was marked by unimportant oscillations. This influence of the season he attributed to the effect of temperature and moisture, and he concluded that a moderate temperature accompanied by humidity furnished the conditions most favorable for the spread of the disease. Further evidence was contributed by Buchan and Mitchell,(106) who tabulated deaths by weeks from all causes distinguished by the Registrar-General in London, for thirty years, 1845–74, and for each disease plotted a curve showing the average weekly deviation from the general weekly mean. For typhoid fever only the six years, 1869–74, were available as prior to 1869 typhus, typhoid and continued fevers were not distinguished. The curve showed a maximum in October and November and a minimum from the middle of May to the end of June, the rise beginning only at the beginning of July, "when the heat of summer has fairly set in."

Pistor,(116) who compared the typhoid cases and deaths for 1883–85 in Berlin, with the height of the ground water and of the river Spree, the precipitation, the height of the barometer, and the temperature of the air and the earth, differed from Virchow and Guttstadt (see above) in finding no marked correspondence with the ground-water variations. As regards temperature, he concluded that "typhoid is in general more abundant in the hot months than in the cold; it appears, however, that mild and damp spring, autumn, and even winter months favor its spread, although not in the same degree as the hot season." Almquist,(119) who studied in detail the seasonal prevalence of fourteen diseases in Göteborg, concluded with regard to typhoid fever that an annual increase in summer or autumn is characteristic, but that this increase is sometimes postponed till the end of the year or the beginning of the next year. A second maximum in January is sometimes combined with the summer maximum. Dryness and the variation in the ground-water level, and above all the warmth in summer and autumn, appeared to him to be operative. Goldberg,(120) in 1889, made an elaborate study of the seasonal prevalence of a large number of diseases in relation to various meteorological conditions, and arrived at the conclusion that the weather influences the mortality from the infectious diseases both by its effect on the multiplication of the germs and their facilities for entrance into the body and by its effect on the vital resistance of the human body in its reaction against the invading organisms. With regard to typhoid fever he analyzed the statistics for Berlin, Hamburg, and Cologne, and summed up his results as follows: —

A. As regards individual disposition, the extremes of air temperature weaken the resistance against typhoid.

B. As regards time-and-place disposition:

1. The rise of typhoid morbidity and mortality in Berlin regularly follows the rise in the temperature of the earth one-half to one meter below the surface.
2. The very different annual periods and annual variations in Berlin, Hamburg, and Cologne correspond throughout to the rhythm of the movements of the ground water.
3. The distribution of rainfall in Berlin and Hamburg, if allowance be made for evaporation, explains satisfactorily the variations both in the height of the ground water and the frequency of typhoid fever.

Goldberg noted what so many other observers have failed to consider that not only the temperature of a given month but also the course of the temperature curve during the months immediately preceding, must be considered; thus the same mean monthly temperature in May and October need not correspond to the same amount of typhoid. He saw that a high temperature favored the spread of typhoid fever, and believed that this was due to a lowering of the vital resistance of the human body by extremes of temperature.

The most important evidence bearing upon the relation of heat to the prevalence of typhoid fever was that collected by Davidson in his "Geographical Pathology," published in 1892.(122) This author strongly emphasized the seasonal character of the disease and considered the temperature to be the one factor of prime importance. He stated that in South Australia, Victoria, and New South Wales typhoid attains its maximum in the autumn months of March, April, and May, and its minimum in September, October, and November. In Queensland the maximum seems to fall upon the hot season, from November to February. For India, he concluded that in the Bengal Presidency the disease attains its maximum in the second quarter and in Central India, Bombay, and Madras in the third quarter. In considering England and Germany, he mentioned the usual autumnal maximum; and for several countries as quoted below, he gave specific figures as to monthly prevalence.

MONTHLY PREVALENCE OF TYPHOID FEVER.

Compiled from figures given by Davidson.

Place.	Period.	Number of Cases.	Monthly Percentage of Total for Year.											
			J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
Finland	1889	639	3.1	4.2	2.8	2.7	5.3	3.1	11.9	20.5	11.7	12.4	13.6	8.6
France (Paris)	1868–78	—	6.2	5.7	4.6	4.9	4.2	4.9	6.9	12.3	13.5	12.5	13.6	10.3
France (Marseilles)	1886-87	—	6.7	4.2	4.4	4.5	6.5	7.0	10.4	14.6	14.6	11.0	8.2	7.8
Italy	three years	—	6.7	6.5	6.8	7.2	7.3	7.2	9.4	11.2	11.1	10.6	8.6	7.4
Norway	1886–87	3138	11.3	7.3	8.9	8.4	5.8	6.1	7.0	8.1	9.5	10.5	8.7	8.4
Scotland (principal towns)	1876–85	3548	8.5	7.7	7.4	7.4	8.8	7.4	5.9	7.4	9.6	11.7	8.7	9.4
Sweden	1886–87	10743	8.9	6.5	6.8	5.9	6.3	5.7	8.1	10.3	11.5	10.0	11.2	8.7

Davidson also attempted to show the causal relation between typhoid fever and temperature variations from year to year after the method adopted by Soyka in treating of the ground-water theory. In the case of New South Wales he took the figures for the period 1877–87, with a mean summer temperature (December to February) of 71.14 F., and a mean typhoid death rate of 5.02 per 10,000, and divided them to form the two following tables.

SIX YEARS WITH TEMPERATURE AND TYPHOID RATE ABOVE THE MEAN FOR THE WHOLE PERIOD.

	1877.	1878.	1882.	1884.	1885.	1886.
Mean Summer Temperature	71.40	72.00	71.17	71.47	71.87	72.10
Mean Typhoid Death Rate	5.96	6.70	5.66	5.86	5.40	6.03

FIVE YEARS WITH TEMPERATURE AND TYPHOID RATE BELOW THE MEAN FOR THE WHOLE PERIOD.

	1879.	1880.	1881.	1883.	1887.
Mean Summer Temperature	71.00	70.17	70.03	70.07	71.10
Mean Typhoid Death Rate	3.84	3.31	3.50	4.76	4.24

Again, in the case of England, Davidson separated from the period 1863–87, four years in which enteric fever was unusually prevalent, and five years which were remarkably free from that disease, and tabulated the relative mean temperatures for those years as follows:—

Four Years with Maximum Typhoid.			Five Years with Minimum Typhoid.		
Year.	Difference between Temperature and Mean Temperature, 1863–87.		Year.	Difference between Temperature and Mean Temperature, 1863–87.	
	For the Year.	For the Third Quarter.		For the Year.	For the Third Quarter.
			1867	—0.7	—0.7
1865	+1.0	+2.1	1877	+0.1	—1.9
1878	+0.3	+0.4	1879	—3.1	—2.3
1880	+0.1	+1.0	1881	—0.6	—0.4
1884	+1.4	+2.3	1885	—0.7	—1.3

These investigations of the yearly variations in typhoid fever are of considerable interest and should be extended; but the differences shown by Davidson are so small and the material so limited as to preclude the drawing of any general conclusions.

The clearest and most definite statement of the effect of temperature upon the spread of typhoid fever that we have seen was made by Professor Woodhead in testifying before the Royal Commission on Metropolitan Water Supply in 1893.(123) Having spoken of the importance of spring floods in carrying infection into water-supplies, he was asked why the maximum of typhoid occurred in autumn instead of at the time of the greatest floods, and his reply was as follows: —

> "You were speaking just now of the conditions under which the typhoid bacillus develops, and you were speaking of it as being a pathogenic organism, and therefore as not competing on equal terms with the saprophytic organisms; and here the matter of temperature alone plays such a very important part that it cannot be left out of consideration. Although you have in February the highest point of floods, you have the temperature so low that the typhoid bacillus could scarcely develop under any conditions, whereas when you come to August, when the temperature is much nearer that of the body, that is, the temperature under which the typhoid bacillus can exist, then the conditions become so much more favorable that the organism can live more readily, more easily, and become more virulent outside the body than it can when the temperature is put very much lower, and, therefore, although at flood times the highest flood points one would expect (if you leave out the temperature) the typhoid bacillus to do the greatest amount of damage, still the temperature is so low that the presence of the bacillus is practically a matter of no importance at that period, and it is only when you get to the flood periods when the temperature is higher that you can take these statistics as bearing on the point. But beyond this, should there be a sporadic case of typhoid due to the use of contaminated water, the conditions for the propagation of the disease are not nearly so favorable during the cold months of February as they are in the hotter months of the year, and therefore the health returns and the tables would be much less affected, not only at the time of the primary outbreak but for some little time afterwards."

Plausible as the conclusions of Murchison, Davidson, and Woodhead appear, they have not gained wide acceptance, and in Germany have been utterly ignored, except by Liebermeister in the passage quoted above. In the same year that his statement appeared, Oesterlen (105) published some figures on the quarterly prevalence of typhoid as given below, and concluded: "That temperature exerts no, or at least a very secondary, influence, is obvious from the very small difference which often appears between the different seasons, and from the circumstance that typhoid epidemics may arise and culminate at the extremes of temperature, in great cold as well as great heat."

QUARTERLY PREVALENCE OF TYPHOID.

After Oesterlen.

Place.	Period.	Winter.	Spring.	Summer.	Autumn.
Geneva	—	180	109	105	203
London	1849–53	2813	2527	2916	3305
Nassau	1818–56	670	470	486	863
Massachusetts	1845–49	429	259	528	1132
Lowell	1840–47	130	102	163	250
Berlin (average monthly deaths)	1830–38	27	18	23	41

A little later, Sander(107) gave a table showing the quarterly distribution of typhoid fever in Berlin, Munich, Halle, Hamburg, Schleswig-Holstein, Dresden, Leipsic, and Chemnitz, and stated that the winter in Munich and the autumn in most other places is the period of special incidence, while May and June are always the months which are most exempt. In 1881, Oldendorff(109) published a few figures as to quarterly prevalence, and repeated Oesterlen's conclusion as to the limited importance of the temperature factor.

In the second edition of the "Geographical and Historical Pathology,"(112) Hirsch devoted considerable space to a consideration of the meteorological factors affecting the spread of typhoid fever. He quoted first numerous earlier observers, to whom references are given in his bibliography. Zülzer at Berlin and Trier at Copenhagen thought that hot and dry weather favored the disease, while others held a wet summer to be a contributory cause. Schiefferdecker at Königsberg, Pribram and Popper at Prague, and Jacoby at Breslau believed they had traced a connection between typhoid and the ground-water level. Hirsch then gave the very valuable tables of seasonal prevalence reproduced below, and in comment remarked, "The result obtained from these tables, that the amount of the sickness touches its highest point in autumn, is fully borne out by the facts as to the season of greatest prevalence of typhoid in many other localities." He cited Schwerin, Bremen, Iceland, Malta, Italy, the Cape, Greenland, and Newfoundland; and added, "All the more noteworthy is the circumstance that, in tropical and subtropical regions, it is chiefly the hot months that form the typhoid season," quoting Algiers, Tunis, Japan, India, Cochin China, Bermuda, and Cuba. An analysis of the typhoid statistics of Berlin from 1871 to 1878 failed to show any correspondence between the amount of typhoid in any given year and the excess of temperature compared with the mean for the whole period; and the author concluded his consideration of the subject as follows: "That no special importance in this connection can be ascribed to the temperature of the air — high or low — *by itself*, follows from the fact that the acme of the disease falls variously in various regions within higher latitudes, either in autumn or in winter; while, in the tropics, it falls mostly at the time of the greatest heats."

MONTHLY DISTRIBUTION OF TYPHOID FEVER.

After Hirsch.

Place.	Period.	Months.											
		J.	J.	A.	S.	O.	N.	D.	J.	F.	M.	A.	M.
Christiania *	1845–64	154	281	402	393	437	768	602	517	335	283	196	182
Drammen *	1861–67	46	100	149	180	253	251	202	141	92	88	56	55
Copenhagen *	1842–58	162	254	428	588	526	317	328	195	105	103	92	100
Hamburg	1873–80	82	82	122	116	147	127	158	146	149	125	90	102
Berlin	1854–79	850	1159	1616	1879	1965	1540	1184	997	919	854	921	910
Breslau	1863–78	187	215	244	287	267	220	202	197	192	192	164	154
Leipzig *	1851–65	64	98	137	135	144	99	76	100	60	54	44	41
Chemnitz *	1837–75	171	208	303	300	245	185	241	148	166	121	112	154
Prague *	1874–76	78	90	69	79	76	84	115	191	122	119	106	110
Nassau *	1818–59	1118	1406	1742	2093	2350	2207	1946	1850	1584	1428	1060	848
Frankfort-a-M.	1863–80	52	74	91	106	113	93	76	60	58	50	50	43
Stuttgart	1852–77	69	76	83	87	88	108	122	106	84	90	73	66
Munich	1852–68 1873–79	408	377	379	365	363	425	619	718	783	699	548	444
Neufchatel Lausanne	1835–52	57	72	95	125	159	92	88	81	49	52	25	38
Basel	1824–73	169	186	202	237	237	236	193	192	143	137	121	160
London *	1848–62	163	220	333	361	377	334	222	197	122	136	89	103
Glasgow *	1871–79	12	15	30	43	36	31	20	23	18	29	18	17
Paris	1867–78	205	289	511	559	522	565	429	259	240	192	205	176
Boston *	1840–47	30	47	86	92	98	60	48	39	43	40	21	41
Pittsburg	1873–77	27	32	65	64	90	65	52	53	37	43	44	53

* Hospital admissions. Other figures refer to reported deaths.

SEASONAL RATIO OF TYPHOID.

After Hirsch.

Place.	Autumn.	Winter.	Summer.	Place.	Autumn.	Winter.	Summer.
Copenhagen	4.9	2.1	2.9	Geneva	1.9	1.7	1.0
Drammen	3.4	2.2	1.5	Chemnitz	1.9	1.4	1.8
Lausanne	3.3	1.9	1.9	Basel	1.7	1.3	1.3
London	3.2	1.7	2.2	Glasgow	1.7	.9	.9
Paris	2.9	1.6	1.8	Pittsburg	1.5	1.0	.9
Massachusetts	2.8	1.3	1.6	Breslau	1.5	1.2	1.3
Leipzig	2.7	1.7	2.1	Sweden	1.2	1.2	1.1
Christiania	2.4	2.2	1.3	Hamburg	1.2	1.3	.9
Boston	2.4	1.2	1.6	Stuttgart	1.2	1.3	1.0
Frankfort-a-M.	2.2	1.3	1.5	Munich	.7	1.3	.7
Berlin	2.0	1.2	1.4	Prague	.7	1.3	.7
Nassau	2.0	1.6	1.3				

These ratios refer to a value of 1 for the Spring Typhoid. Spring is considered to begin with March.

The work which has been done upon the seasonal prevalence of typhoid fever within the last ten years has, if anything, only made the subject more obscure. Magelssen, in his classic brochure (121) on the dependence of diseases upon the weather, in which he showed so clearly the unfavorable influence of extreme low temperatures upon the general mortality, only alluded to typhoid in passing, stating that it is most abundant in the latter months of the year. Körösi, in 1894,(124) made an elaborate comparison of the reported cases of the infectious diseases in Berlin with the moisture and temperature by periods of five days, a week and a month, according to the incubation period of the disease. He criticised those observers, especially Haller, who have studied the relation of disease to season, in general, on the ground that such a comparison can throw no light on the causation of disease as the phenomena involved are too complex. His method consisted in the division of his pentads and months into five groups, designated as very cold, fairly cold, fairly warm, warm, and hot, and the calculation of the relative prevalence of the disease in each group of periods. He thus eliminated all the effects of the weather preceding the period considered and obscured the facts. When analyzed into his five temperature groups, two maxima appeared, — one in the hot, one in the fairly cold months, — and he concluded that no positive relation is shown. Moisture, on the other hand, appeared to exert an appreciable effect, and he finally concluded that the maximum of morbidity occurred in dry weather with medium warmth, while the minimum was reached when a medium temperature coincided with an excess of moisture. Fodor, in 1896,(125) declared that "the striking dependence on the warmth, and on the season which is so characteristic of cholera is almost entirely wanting in typhoid fever." In the same year, Jessen(126) published curves which showed the monthly prevalence of measles, croup, and diphtheria, typhoid fever, cholera, pneumonia, phthisis, and diarrhœal diseases of children in comparison with variations in wind, temperature, humidity, and rainfall. With regard to typhoid fever he concluded that temperature was the only factor which affected the disease, and that this was only of slight importance, as typhoid fever, though occurring principally in the cold months (!), sometimes attained a maximum when the temperature was high. Knoevenagel (127) noted the increased prevalence of typhoid fever in Mecklenburg-Schwerin at the end of July and in August and September. Berger (129) and Ruhemann,(130) in 1898, emphasized the importance of atmospheric conditions in ætiology, and criticised the exclusive attention paid to the bacteriological factors in disease. The former author, after an excellent review of literature on the influence of weather on various diseases (tuberculosis, pneumonia), published curves of morbidity from diphtheria, scarlet fever, measles, and typhoid fever in a rural district for a period of four years. Typhoid fever, although the total number of cases was only twenty-two, showed a maximum in August and a minimum between November and February. Berger concluded that typhoid fever is most prevalent with a falling barometer and a rising thermometer, hygrometer, and dew point, and that its occurrence is favored by damp and cloudy weather. Ruhemann alluded only in passing to typhoid fever, mentioning its summer maximum. Finally, in 1899, Weichselbaum(131) concluded that "no seasonal distribution of typhoid, no preference of that disease for any special time of year, at least in the marked sense in which it has been shown for cholera, has been, or will be demonstrated." *

Curschmann, in the latest monograph on typhoid fever,(132) notes that this disease shows a "constant and for many countries a uniform relation to the seasons." "Everywhere the increased frequency occurs during the late summer and autumn months." "The period of least prevalence of typhoid fever is everywhere the spring and the beginning of the summer, especially the months of March, April, and May." He quotes the figures for London (Murchison), Dresden (Fiedler), and the Hamburg epidemic of 1886–87, and gives a table for Leipsic which is reproduced below. The London and Leipsic figures, when plotted, show very regular curves.

CASES OF TYPHOID FEVER RECEIVED INTO JACOBSSPITAL, LEIPSIC, FROM 1880 TO 1892.

J	F	M	A	M	J	J	A	S	O	N	D.
122	96	97	78	71	75	136	252	240	193	150	88

In commenting on these facts Curschmann says: "The causes for this remarkable uniformity in the relations of typhoid fever to season are as yet wholly unknown.

---

* Behrens (*Einfluss der Witterung auf Diphtherie, Scharlach, Masern und Typhus, Arch. f. Hyg.*, XL., 1901, 1) has recently published an exhaustive study on the influence of weather on the prevalence of diphtheria, scarlet fever, measles, and typhoid. His method consists in the arrangement of the individual months for a period of five years in classes according to temperature, humidity, and precipitation, and the tabulation of the morbidity and mortality for the various classes of months. The cities treated are Carlsruhe, Berlin, Bremen, and Breslau. A series of tables is appended of morbidity in Carlsruhe from the four diseases treated by five-day periods with an elaborate analysis of the meteorological conditions. The results of the investigation are conflicting and inconclusive. With reference to typhoid fever, Dr. Behrens sums up the evidence from his own work and that of Jessen and Körösi as follows: "Typhoid reaches its maximum in hot weather at Carlsruhe, Berlin, and Breslau, in cold weather at Hamburg, and in weather of medium warmth at Budapest. At Bremen no influence of temperature can be shown. Carlsruhe, Berlin, Breslau, and Budapest agree in the fact that the number of typhoid cases is greatest when the humidity is least; in Bremen, on the other hand, the maximum occurs when the hygrometer is highest. A heavy precipitation and a maximum of rainy days favor the disease in all cases." His final conclusion with regard to this disease is as follows: "Typhoid cases are as numerous with a warmer as with a cooler temperature, but are markedly favored in their occurrence by cloudy and rainy weather."

The universality of the relation, its recurrence in all possible, remotely situated regions, indicate that it is dependent not upon local, but upon general conditions, possibly such as are responsible for the power of multiplication and the vital activity of the typhoid germ itself. Although much is known with regard to the details in this connection, an insight into the solution of general questions is wanting, particularly the relation of the poison to important cosmic conditions. It is, therefore, better for the present to leave a glaring deficiency rather than to bridge it over with unstable theories."

II. STATISTICAL STUDIES BY THE AUTHORS ON SEASONAL VARIATIONS IN TEMPERATURE AND ON THE PREVALENCE OF TYPHOID FEVER IN VARIOUS COUNTRIES.

It appears, then, from a review of the literature that, although most observers have noted a characteristic seasonal distribution of typhoid fever, others, including some of those who have written most recently, have denied the existence of such regular variations. Of those who realized that the variations did exist, a few sought an explanation in the factor of temperature. Their views did not, however, gain acceptance, as the evidence furnished was insufficient; and the common view, among medical men and sanitarians, has been that the fall maximum of typhoid fever was an unexplained phenomenon.

The bacteriological work on the effect of low temperatures upon the bacillus of typhoid fever, reported in the first section of this paper, lent force to the idea that the temperature really might in itself exercise a direct effect upon the ætiology of this disease. We therefore determined to see whether the relation shown by Murchison, Liebermeister, and Davidson for a few places could be demonstrated by a more exact examination of statistics collected from a wider field.

We have, accordingly, brought together statistics of the monthly variations in temperature and in the prevalence of typhoid fever for thirty communities, as follows: The States of New York and Massachusetts, the District of Columbia, and the cities of Atlanta, Baltimore, Boston, Charleston, Chicago, Cincinnati, Denver, Mobile, Newark, New Orleans, New York, Oakland, Philadelphia, St. Paul, and San Francisco, in the United States; the city of Montreal in Canada; the cities of Berlin, Dresden, Leipsic, London, Munich, Paris, and Vienna in Europe; the Empire of Japan, and the British Army in India, in Asia; and the cities of Buenos Ayres and Santiago de Chile in South America. Four continents and both hemispheres are thus represented, and a very wide range of climate. (See pp. 540–566.)

The mean monthly temperatures for the American cities were obtained from the reports of the United States Weather Bureau; those for the German cities, from the publications of the astronomical observatories in their respective districts; and those for London, Paris, Montreal, Buenos Ayres, and Santiago from special local publications mentioned in connection with the tables. For the States of New York and Massachusetts, it was assumed that the temperature of New York City and Boston would serve without serious error. For Japan, where the range of temperature is rather wide, an average was taken of the record of ten stations in different parts of the Empire, as given by the Central Meteorological Observatory. In the case of India, it appeared inadvisable to attempt to calculate an average for the whole empire, as the seasons in the different districts are so very different. The typhoid figures are, therefore, compared with two sets of temperature values, for Central India, and for the Punjab, taken from Hann's "*Klimatologie*," which give a fair idea of the two most important meteorological zones. For each of the cities and stations, with one or two exceptions, the figures for ten years have been used in order to secure a reliable average; and the mean monthly temperatures finally obtained have all been reduced to the Fahrenheit scale for uniformity and convenience in plotting the curves.

The typhoid statistics include records of hospital admissions at the two hospitals of Santiago de Chile, of hospital admissions in the British Army in India, of reported cases at Newark and of deaths in all other instances. The figures for the American States and cities, for Montreal, London, and Paris, were obtained from the published reports of the local Departments of Health, supplemented in some cases by information furnished in reply to correspondence; the German statistics were taken from the "*Veröffentlichungen des Kaiserlichen Gesundheitsamtes;*" for Japan, the Annual Reports of the Central Sanitary Bureau, for India, the Parliamentary blue-books, and for the South American cities, local sanitary periodicals referred to in the tables, were consulted. The figures for ten years were averaged in each case except as follows: for Vienna and Japan the period was five years; for Atlanta, six years; for Montreal and New Orleans, eight years; for Denver and Paris, nine years; for the Army in India, eleven years; for Buenos Ayres, twenty-two years. In each case the average number of deaths per month has been reduced to a ratio of one hundred deaths per year, the final figure for each month representing the number that occur in that month for every hundred deaths in the year. Thus the absolute amount of the disease is entirely eliminated, and only its seasonal distribution considered. The value of the statistics will not therefore be impaired by errors of registration, which it may be assumed will not vary from month to month.

Finally, the monthly values for temperature and typhoid prevalence have been plotted on the appended plates in order to show graphically the relation of the two curves. For each locality the abscissæ represent the successive months, and the ordinates the monthly temperature and percentage of annual typhoid. We should not, however, expect the effect of January temperatures to be manifest in the typhoid death-rate until March, as about two months will be taken up in the transfer of the infection to the victim, in the incubation of the disease, and in its course toward a fatal termination. Accordingly, in order to make the relation of the two curves more striking, the typhoid curve has in each case been shifted along to the left by just two months, so that March typhoid comes just above January temperature, and so on. Where cases and not deaths have been considered (Santiago, Newark, India) the curve has been only moved along by one month. This transposition does not, of course, alter the shape of the curves or their relation to each other, but only makes that relation clearer to the eye. (See Plates I.–VIII.)

BOSTON.

Monthly Typhoid Deaths.

From Reports, Local Department of Health.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1888	7	5	5	11	3	11	11	19	31	42	17	18
1889	6	7	7	7	9	12	17	35	33	23	17	13
1890	7	5	7	7	7	8	9	20	27	20	19	19
1891	8	4	11	9	8	4	7	14	29	29	15	16
1892	2	5	7	7	9	6	6	15	18	29	18	15
1893	13	9	6	10	13	12	7	15	14	26	17	6
1894	3	5	5	7	7	4	4	18	30	27	20	11
1895	8	3	6	7	11	8	9	26	28	26	13	18
1896	14	6	2	5	6	7	8	13	30	34	23	14
1897	14	7	9	11	8	9	10	25	27	22	18	13
Average	8.1	5.6	6.5	8.1	8.1	8.1	8.8	20.0	26.7	27.8	17.7	14.3
Ratio of 100	5.1	3.5	4.1	5.1	5.1	5.1	5.5	12.5	16.7	17.4	11.1	8.9

Mean Monthly Temperature.

From "Monthly Weather Review," U. S. Weather Bureau.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1888	20	28	32	42	52	67	68	69	59	47	43	34
1889	36	26	38	48	60	69	69	67	63	48	45	38
1890	32	33	35	46	57	64	71	70	63	51	42	26
1891	31	32	34	48	56	65	69	70	67	52	41	40
1892	28	28	33	48	56	70	73	70	62	53	41	30
1893	21	27	34	44	56	65	71	70	60	55	42	30
1894	30	27	42	47	58	69	74	68	65	54	38	32
1895	29	25	35	46	60	67	69	71	66	50	45	36
1896	25	29	32	47	60	66	72	71	62	50	46	30
1897	28	31	37	49	58	62	72	70	63	54	41	34
Average	28	29	35	46	57	66	71	70	63	51	42	33

NEW YORK CITY.

MONTHLY TYPHOID DEATHS.

From Reports, State Board of Health.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1887	28	13	21	11	11	16	33	51	53	38	26	22
1888	12	14	13	11	23	11	35	42	82	52	37	33
1889	27	15	21	18	15	19	31	71	57	57	40	21
1890	20	28	13	12	11	11	31	49	64	49	34	29
1891	14	11	17	13	20	23	28	57	65	56	51	29
1892	15	25	17	19	23	23	52	53	57	55	31	30
1893	22	19	29	25	29	23	21	35	42	70	41	26
1894	22	11	17	18	11	14	28	42	57	46	32	28
1895	17	16	8	14	13	23	27	37	46	48	37	36
1896	20	17	11	12	10	13	25	42	38	39	34	36
Average	19.7	16.9	16.7	15.3	16.6	17.6	31.1	47.9	56.1	51.0	36.3	29.0
Ratio of 100	5.6	4.8	4.8	4.2	4.8	5.1	8.7	13.5	15.8	14.4	10.1	8.2

MONTHLY TEMPERATURE.

From "Monthly Weather Review," U. S. Weather Bureau.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1888	26	32	32	48	58	71	70	72	63	49	45	34
1889	38	28	41	52	62	70	73	71	66	52	47	41
1890	40	40	37	51	61	70	73	72	67	55	46	31
1891	35	37	38	52	60	70	71	74	70	54	44	42
1892	30	33	35	50	59	72	75	74	66	55	43	31
1893	23	30	36	48	59	69	75	74	64	58	44	35
1894	35	30	44	50	61	71	76	73	70	57	42	37
1895	30	25	36	48	59	70	71	74	70	51	46	37
1896	28	30	32	50	64	66	73	73	65	52	48	32
1897	29	33	39	49	59	65	73	71	65	56	44	36
Average	31	32	37	50	60	69	73	73	67	54	45	36

MASSACHUSETTS.

Average Weekly Typhoid Deaths for each Month.

From Reports, State Board of Health.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1886	6	5	4	5	3	3	4	10	15	16	11	10
1887	4	8	8	7	6	7	5	14	22	16	12	7
1888	6	5	6	7	5	6	5	10	16	26	11	8
1889	6	8	7	5	6	6	7	15	18	16	13	8
1890	6	7	5	4	5	5	4	9	16	14	18	15
1891	15	11	7	7	4	2	4	6	14	15	11	9
1892	6	5	7	4	5	5	6	9	11	37	11	12
1893	9	8	5	6	5	5	4	9	13	17	11	10
1894	5	7	4	5	6	2	4	7	16	15	15	9
1895	4	2	5	6	5	5	5	12	16	12	10	11
Average	6.7	6.6	5.8	5.6	5.0	4.6	4.8	10.1	15.7	18.4	12.3	9.9
Ratio of 100	6.4	6.3	5.5	5.3	4.7	4.4	4.5	9.6	13.9	17.4	11.7	9.4

NEW YORK STATE.

Monthly Typhoid Deaths.

From Reports, State Board of Health.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1887	72	57	72	56	37	54	102	194	248	182	149	104
1888	64	84	81	45	59	45	73	174	279	288	153	138
1889	89	71	69	78	63	45	117	224	247	261	169	117
1890	117	94	72	73	72	69	101	167	234	240	216	157
1891	138	127	121	103	88	90	97	171	287	290	241	183
1892	116	98	96	77	71	75	131	182	282	205	184	147
1893	120	101	115	111	93	83	87	157	227	253	180	158
1894	105	86	131	94	85	72	93	183	229	234	189	139
1895	108	99	99	115	92	81	108	156	220	265	204	169
1896	158	121	103	87	59	66	103	171	221	195	132	126
Average	109	94	96	84	72	68	101	178	247	241	182	144
Ratio of 100	6.7	5.8	5.9	5.2	4.5	4.2	6.3	11.0	15.3	14.9	11.3	8.9

ST. PAUL.

Monthly Typhoid Deaths.

From Reports, Local Board of Health.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1888	7	8	4	5	6	4	6	14	27	29	22	10
1890	7	4	2	5	0	2	2	17	11	6	6	3
1891	3	6	4	1	2	3	2	6	12	10	7	5
1892	2	1	6	1	0	0	2	1	4	12	7	11
1893	3	2	1	0	2	3	1	11	8	9	5	6
1894	0	1	1	1	0	2	2	4	6	5	6	4
1895	3	5	3	1	1	3	4	5	2	8	1	2
1896	7	6	3	3	1	1	0	5	0	4	5	2
1897	0	2	2	2	1	1	0	1	3	3	6	1
Average	3.6	3.9	2.9	2.1	1.4	2.1	2.1	7.1	8.1	8.4	7.2	4.9
Ratio of 100	6.6	7.2	5.4	3.9	2.7	3.9	3.9	13.2	15.1	15.7	13.4	9.1

Mean Monthly Temperature.

From "Monthly Weather Review," U. S. Weather Bureau.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1888	—1	12	18	40	50	67	72	66	55	43	33	24
1889	20	10	37	48	56	64	71	70	59	45	29	29
1890	10	18	22	48	52	70	72	65	58	46	36	24
1891	21	11	23	48	58	65	66	67	66	48	26	27
1892	10	21	28	42	51	65	71	69	63	51	28	15
1893	3	9	23	39	54	71	73	69	62	49	30	12
1894	10	14	35	49	58	72	76	72	64	49	27	27
1895	6	11	28	52	59	67	70	70	65	44	31	21
1896	16	21	25	47	63	68	71	70	56	45	22	23
1897	9	19	24	46	57	64	74	66	68	53	29	15
Average	10	15	27	46	56	67	72	68	62	47	29	22

DENVER.

Monthly Typhoid Deaths.

From Reports, Local Department of Health.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1888	8	1	3	0	2	5	14	22	24	31	21	3
1889	4	0	1	1	4	1	14	23	51	55	22	12
1890	7	5	2	1	9	7	17	31	56	72	50	30
1891	13	9	4	3	2	3	6	11	15	17	9	7
1892	2	1	2	3	2	6	2	12	9	9	15	1
1893	4	4	0	5	8	5	8	4	5	10	15	3
1894	4	2	1	1	3	6	3	8	8	7	48	8
1895	5	1	2	1	2	2	2	5	8	6	8	2
1896	5	0	2	1	4	0	6	13	28	17	12	3
Average	5.8	2.6	1.9	1.8	4.0	3.9	8.0	15.4	22.7	24.9	22.2	7.7
Ratio of 100	4.8	2.1	1.6	1.5	3.3	3.2	6.7	11.9	18.9	20.7	18.5	6.4

Mean Monthly Temperature.

From "Monthly Weather Review," U. S. Weather Bureau.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1888	27	39	33	53	53	68	71	65	61	48	34	34
1889	27	30	43	51	55	64	72	73	60	52	32	40
1890	28	34	41	48	58	68	72	69	62	49	40	39
1891	25	27	32	48	56	63	70	69	64	52	38	31
1892	26	33	36	46	51	65	72	71	66	50	43	27
1893	38	31	38	45	54	69	73	70	63	51	39	38
1894	31	25	40	50	59	66	72	71	63	54	45	32
1895	28	27	37	50	56	62	67	70	66	51	38	34
1896	37	38	37	50	59	68	72	72	61	50	36	39
1897	27	31	36	47	61	65	70	70	66	51	41	28
Average	29	31	37	49	56	66	71	70	63	51	39	34

MONTREAL.

Monthly Typhoid Deaths.

From Reports, Local Department of Health.

Year.	J.	F.	M.	A.	M.	J	J.	A.	S.	O.	N.	D.
1888	5	2	4	2	4	4	4	20	24	14	6	5
1889	3	3	2	3	2	2	3	15	19	8	6	6
1891	0	0	8	1	2	2	4	7	13	10	8	7
1892	4	6	3	0	1	2	4	6	8	12	15	4
1893	6	3	2	4	4	3	5	2	6	8	2	5
1894	6	3	4	5	3	0	1	6	6	1	6	1
1895	1	2	1	2	5	2	4	3	10	6	5	3
1896	3	3	2	2	3	1	7	4	4	9	4	4
Average	3.5	2.7	3.2	2.4	3.0	2.0	4.0	7.9	11.2	8.5	6.5	4.4
Ratio of 100	5.9	4.6	5.5	4.0	5.1	3.4	6.7	13.3	18.9	14.3	10.9	7.4

Mean Monthly Temperature.

From Reports, Local Department of Health.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1888	4	12	23	37	54	66	68	64	55	40	33	23
1891	15	19	27	40	52	64	69	65	58	46	32	7
1892	15	17	26	42	52	65	66	67	62	45	35	30
1893	15	18	23	41	53	66	70	66	57	46	33	19
1894	13	13	32	45	56	66	69	63	60	49	30	23
1895	15	14	22	41	58	70	67	66	60	41	34	22
1896	12	15	20	41	58	65	69	67	57	43	35	18
Average	13	15	25	41	55	66	68	65	58	44	33	20

BALTIMORE.

MONTHLY TYPHOID DEATHS.

From Reports, Local Department of Health.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1888	7	8	6	6	5	10	4	26	34	21	17	17
1889	15	7	14	4	12	16	8	30	26	14	19	26
1890	10	12	15	19	13	13	29	36	30	34	25	11
1891	15	8	3	5	9	6	9	14	22	29	17	13
1892	13	9	8	9	11	8	16	30	26	29	21	13
1893	20	5	11	10	4	13	23	33	32	27	34	12
1894	12	8	6	14	14	8	18	39	28	31	21	23
1895	11	11	6	9	7	3	24	12	27	31	19	13
1896	7	11	4	11	11	13	19	23	29	28	22	10
1897	7	8	6	6	6	8	13	36	36	27	19	17
Average	12.7	8.9	7.9	9.3	9.2	9.8	16.3	27.9	29.0	27.1	21.4	15.5
Ratio of 100	6.6	4.6	4.1	4.8	4.8	5.1	8.4	14.4	15.0	14.0	11.1	8.0

MEAN MONTHLY TEMPERATURE.

From "Monthly Weather Review," U. S. Weather Bureau.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1888	29	35	37	53	63	73	74	75	64	51	47	36
1889	39	31	43	55	66	71	77	74	66	54	48	46
1890	44	43	42	54	64	75	75	74	68	57	48	35
1891	38	41	39	56	62	71	72	74	71	55	44	44
1892	32	37	37	52	63	76	76	76	66	56	44	33
1893	25	34	40	53	61	72	77	75	67	57	44	39
1894	37	34	48	52	65	73	78	73	71	57	43	38
1895	31	26	41	53	62	74	73	77	72	53	47	39
1896	34	36	38	57	69	71	78	76	68	55	51	36
1897	32	37	45	53	63	70	77	74	69	58	46	39
Average	34	35	41	54	64	73	76	75	68	55	46	38

LONDON.

WEEKLY TYPHOID DEATHS AND AVERAGE MEAN TEMPERATURE.

From the Weekly Returns of the Registrar-General.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
Deaths . . .	13	14	13	11	12	7	10	9	9	9	9	7	8
Temperature .	38	38	38	39	40	39	40	40	41	41	42	42	45
	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.
Deaths . . .	9	6	8	7	8	7	9	8	8	7	9	9	9
Temperature .	46	46	48	48	50	52	54	56	57	58	59	60	61
	27.	28.	29.	30.	31.	32.	33.	34.	35.	36.	37.	38.	39.
Deaths . . .	8	10	7	9	10	9	13	12	19	15	16	17	17
Temperature .	62	63	63	62	62	63	62	61	60	59	58	56	55
	40.	41.	42.	43.	44.	45.	46.	47.	48.	49.	50.	51.	52.
Deaths . . .	17	19	19	18	20	19	19	20	17	16	19	15	16
Temperature .	53	51	49	47	47	45	42	41	41	41	40	39	38

Weekly typhoid rate is average for ten years, 1888–1897. Temperature is average for years, 1840–1890.

AVERAGE WEEKLY TYPHOID DEATHS FOR EACH MONTH.

	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
Deaths	13.0	9.0	8.0	7.0	8.0	8.0	8.0	16.0	16.0	18.0	19.0	16.0
Ratio of 100 . . .	8.9	6.2	5.5	4.8	5.5	5.5	5.5	11.0	11.0	12.3	13.0	11.0
Temperature . . .	38.0	40.0	42.0	47.0	53.0	59.0	62.0	62.0	57.0	50.0	43.0	40.0

LEIPSIC.

MONTHLY TYPHOID DEATHS.

From "Veröffentlichungen des Kaiserlichen Gesundheitsamtes."

	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1888	1	2	1	1	1	3	2	1	1	0	4	2
1889	2	2	2	2	1	0	4	6	6	6	3	2
1890	6	1	1	0	1	5	2	7	6	4	3	6
1891	5	5	4	6	5	1	6	5	6	4	3	4
1892	0	3	1	0	1	1	4	3	4	7	3	2
1893	2	2	0	0	0	3	4	1	6	2	1	6
1894	1	2	2	1	5	5	4	3	2	4	5	4
1895	0	3	1	1	2	2	0	3	8	5	6	2
1896	2	3	2	5	1	1	1	3	2	2	3	7
1897	3	5	3	1	2	1	2	5	8	3	4	0
Average	2.2	2.8	1.7	1.7	1.9	2.2	2.9	3.7	4.9	3.7	3.5	3.5
Ratio of 100	6.3	8.1	4.9	4.9	5.5	6.3	8.4	10.7	14.1	10.7	10.1	10.1

MEAN MONTHLY TEMPERATURE. 1864–1890.

From "Amtliche Publication des Königl. sächsischen meteorologischen Institutes. Das Klima des Königreiches Sachsen." Heft III, 1895.

	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
Centigrade	–1	0	3	8	13	17	18	17	14	8	3	0
Fahrenheit	30	32	37	46	55	63	64	63	57	46	37	32

BERLIN.

MONTHLY TYPHOID DEATHS.

From " Veröffentlichungen des Kaiserlichen Gesundheitsamtes."

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1888	38	19	10	11	8	10	18	22	13	15	11	13
1889	11	21	58	23	14	11	28	20	23	18	36	27
1890	14	15	11	9	10	8	10	16	18	18	9	5
1891	9	7	16	7	9	9	7	20	19	31	20	12
1892	12	6	15	7	10	10	7	9	23	15	10	13
1893	7	6	11	8	13	8	7	19	42	16	18	5
1894	7	9	8	7	7	5	7	5	10	10	5	12
1895	6	7	8	2	4	14	8	16	22	17	8	14
1896	9	6	6	11	8	6	11	14	17	11	4	5
1897	3	1	8	8	5	4	4	20	11	10	7	9
Average	11.6	9.7	15.1	9.3	8.8	8.5	10.7	16.1	19.8	16.1	12.8	11.5
Ratio of 100	8.0	6.7	10.0	6.0	6.0	5.3	7.3	10.7	13.3	10.7	8.7	7.3

MEAN MONTHLY TEMPERATURE.

From " Ergebnisse der meteorologischen Beobachtungen von dem Königlich. Preussischen meteorologischen Institut."

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1888	—1	—2	0	7	14	17	17	17	15	8	4	2
1889	—2	—1	1	9	19	22	18	17	13	9	4	0
1890	3	—1	6	9	16	16	18	19	15	9	4	—4
1891	—3	1	4	6	15	16	18	17	16	11	4	3
1892	—1	1	2	8	13	17	18	20	16	9	2	—1
1893	—7	2	5	9	13	17	19	18	13	11	3	1
1894	—1	3	6	11	13	16	20	17	12	9	5	1
Average	—2	0	3	8	15	17	18	18	14	9	4	0
Fahrenheit	28	32	37	46	59	63	64	64	57	48	39	32

EMPIRE OF JAPAN.

MONTHLY TYPHOID DEATHS.

From Annual Reports of the Central Sanitary Bureau of Japan.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1890	568	386	380	402	540	527	603	838	1159	1309	977	775
1891	556	285	264	392	724	1038	1028	940	1255	1286	1009	837
1892	541	382	366	405	468	628	734	938	1165	1252	921	729
1893	508	361	368	340	450	520	646	827	1190	1262	1016	695
1894	515	319	226	256	338	515	681	1068	1298	1141	995	702
Average	538	347	321	359	504	646	738	922	1203	1250	984	748
Ratio of 100	6.3	4.1	3.8	4.2	5.9	7.5	8.6	10.8	14.1	14.6	11.5	8.8

MEAN MONTHLY TEMPERATURE. (10 stations.) (3–6 years.)

From " The Climate of Japan," Central Meteorological Observatory, Tokio, 1893.

Stations.	J	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
Kumamoto	3	7	10	16	19	22	26	27	25	18	12	8
Matsuyama	4	6	8	13	17	21	25	26	23	17	12	9
Hiroshima .	3	5	8	13	19	22	25	27	23	17	11	7
Ozaka . .	4	5	9	14	18	22	26	27	24	17	12	7
Wakayama	5	5	9	14	18	22	26	27	23	17	12	8
Nagano .	—2	0	4	11	14	19	23	24	20	12	7	4
Tokio . .	3	4	7	13	16	21	24	26	22	16	11	6
Hakodate .	—4	—2	3	7	11	14	18	21	18	11	5	1
Sapporo .	—7	—5	0	5	11	15	19	21	17	9	3	—1
Nemuro .	—6	—5	—1	4	7	10	15	18	16	10	4	0
Average .	0	2	6	11	15	19	23	24	21	14	9	5
Fahrenheit	32	36	43	52	59	66	74	75	70	58	48	41

SAN FRANCISCO.

Monthly Typhoid Deaths.

From Reports, Local Department of Health.

Year.	J.	F.	M.	A.	M.	J.	J	A.	S.	O.	N.	D.
1888							12	10	18	13	15	12
1889	6	10	8	13	12	9						
1890	17	6	7	6	4	17	17	13	11	21	14	10
1891	13	6	10	5	9	8	18	16	7	8	11	12
1892	8	6	8	4	4	1	13	14	5	13	11	7
1893	4	5	3	4	3	12	10	11	10	9	16	10
1894	11	7	5	5	9	6	8	13	12	9	10	20
1895	14	11	4	6	5	11	16	5	12	8	7	9
1896	10	6	6	5	7	10	0	8	7	10	7	9
1897	13	2	7	5	3	4	3	4	—	5	4	4
Average	10.7	6.7	6.4	5.9	6.2	8.7	10.8	10.4	10.2	10.7	10.6	10.3
Ratio of 100	9.9	6.1	6.0	5.5	5.8	8.1	10.0	9.7	9.4	9.9	9.8	9.6

Mean Monthly Temperature.

From "Monthly Weather Review," U. S. Weather Bureau.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1888	46	53	52	56	55	61	59	58	59	59	55	52
1889	50	54	57	59	59	60	59	60	65	62	59	51
1890	46	49	54	55	60	59	60	61	60	62	59	50
1891	52	51	55	53	56	60	59	62	62	60	59	50
1892	52	52	54	53	58	57	58	59	60	60	57	51
1893	47	50	51	52	56	56	57	57	59	58	56	52
1894	48	48	51	55	55	56	56	59	63	60	59	50
1895	49	54	52	55	58	59	58	58	61	59	56	49
1896	52	55	54	52	56	57	59	59	60	59	53	53
1897	49	51	49	57	57	59	58	58	61	58	53	51
Average	49	52	53	55	56	58	58	59	61	60	57	51

CINCINNATI.

Monthly Typhoid Deaths.

From Reports, Local Department of Health.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1888	41	34	16	11	6	7	6	12	17	16	22	15
1889	11	14	11	19	7	9	12	14	14	11	12	9
1890	18	11	17	9	14	14	23	24	20	23	23	9
1891	10	17	14	21	14	21	10	16	7	22	22	12
1892	17	10	8	4	4	7	6	10	12	9	11	23
1893	10	14	8	4	14	6	8	15	14	12	12	17
1894	18	11	15	10	10	8	12	6	10	21	11	37
1895	22	12	7	6	5	5	7	7	8	10	8	23
1896	34	22	15	11	11	5	6	14	9	11	11	15
1897	9	8	5	5	10	3	17	9	9	9	6	11
Average	19.0	15.3	12.6	10.0	9.5	8.5	10.7	12.7	12.0	14.4	13.8	17.1
Ratio of 100	12.3	9.9	8.2	6.5	6.2	5.5	6.9	8.2	7.8	9.4	8.9	11.1

Mean Monthly Temperature.

From "Monthly Weather Review," U. S. Weather Bureau.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1888	29	35	39	55	63	74	76	73	63	50	45	36
1889	37	30	46	54	63	70	75	72	66	52	43	48
1890	41	43	40	56	64	78	77	73	66	56	48	36
1891	36	40	38	56	60	74	71	72	70	55	43	42
1892	26	39	38	53	62	75	76	75	68	56	40	32
1893	21	34	42	54	61	73	79	75	70	56	42	36
1894	38	33	49	54	63	75	77	77	72	57	41	37
1895	27	24	41	55	64	76	75	77	73	51	44	37
1896	34	35	37	62	71	73	76	75	65	53	48	38
1897	29	36	46	52	59	72	78	74	71	63	46	36
Average	32	35	42	55	63	74	76	74	68	55	44	38

DISTRICT OF COLUMBIA.

MONTHLY TYPHOID DEATHS.

From Reports, Local Department of Health.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1887							18	32	22	20	18	15
1888	8	7	8	7	3	10	12	23	27	34	19	7
1889	14	7	9	5	6	7	23	18	29	15	18	29
1890	9	6	19	11	10	21	33	26	29	30	21	17
1891	12	6	12	9	5	8	6	22	21	36	26	12
1892	13	13	8	7	8	11	19	21	30	22	25	18
1893	6	7	6	11	11	10	21	24	28	23	23	21
1894	10	5	5	6	5	20	33	30	26	30	24	16
1895	3	8	1	1	1	1	12	27	56	55	24	20
1896	9	8	3	3	4	7	8	15	25	25	18	16
1897	13	4	4	4	6	9						
Average	9.7	7.1	7.5	6.4	5.9	10.4	18.5	23.8	29.3	29.0	21.6	17.1
Ratio of 100	5.2	3.8	4.1	3.5	3.2	5.6	10.0	12.9	15.8	15.7	11.7	9.2

MEAN MONTHLY TEMPERATURE.

From Reports, Local Department of Health.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O	N.	D.
1887							80.5	73.2	65.0	55.4	44.9	37.2
1888	29.2	35.7	37.5	52.9	62.7	73.0	72.9	73.9	63.2	50.5	45.8	35.2
1889	36.8	29.4	42.3	53.2	63.8	69.8	74.2	70.6	65.6	52.5	46.2	45.6
1890	44.2	43.4	41.4	53.7	63.8	74.9	75.1	73.5	67.7	56.2	47.8	34.2
1891	37.3	41.5	38.5	55.4	61.3	71.4	72.0	74.5	79.2	54.4	43.9	43.1
1892	31.7	36.9	37.7	51.5	63.8	76.2	75.7	76.2	66.2	55.0	43.6	33.0
1893	24.0	34.9	41.0	54.0	61.6	72.0	77.0	74.7	66.0	56.4	43.6	38.4
1894	37.7	35.2	48.6	53.2	64.8	73.7	78.0	73.9	71.4	57.8	43.8	37.4
1895	31.6	26.2	41.8	53.8	62.6	74.6	72.7	77.3	72.4	52.1	46.4	38.7
1896	33.3	36.6	38.6	66.5	68.8	71.3	76.6	75.7	67.7	54.0	50.6	35.5
1897	30.9	36.5	46.0	53.0	62.5	69.7						
Average	34	36	41	55	64	73	75	74	68	54	46	38

MOBILE.

Monthly Typhoid Deaths.

Obtained, in correspondence, by courtesy of Local Department of Health.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1889	0	0	2	2	0	2	2	3	1	1	1	2
1890	0	2	0	1	1	2	6	2	0	1	0	1
1891	0	0	0	0	2	0	3	0	4	3	2	0
1892	0	1	0	0	1	1	4	3	1	2	0	1
1893	1	1	1	1	0	4	3	1	2	2	0	0
1894	1	2	0	0	1	2	4	1	1	1	1	1
1895	3	0	0	0	2	1	2	3	4	4	1	2
1896	1	0	0	0	2	1	5	1	0	2	3	1
1897	1	1	0	0	1	3	4	2	5	1	2	0
1898	1	0	2	1	1	2	6	4	2	2	1	1
Average	.8	.7	.5	.5	1.1	1.8	3.9	2.0	2.0	1.9	1.1	.9
Ratio of 100	4.6	4.1	2.9	2.9	6.4	10.4	22.6	11.6	11.6	11.0	6.4	5.2

Mean Monthly Temperature.

From "Monthly Weather Review," U. S. Weather Bureau.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1889	51	51	59	68	70	77	81	79	77	66	56	61
1890	62	61	57	68	73	80	80	80	77	67	61	54
1891	49	59	59	66	72	80	80	80	77	65	57	53
1892	47	57	55	66	72	79	79	80	75	69	58	52
1893	46	58	57	69	74	79	82	81	78	66	58	55
1894	55	53	60	69	74	78	79	80	78	68	57	54
1895	49	43	58	66	72	79	81	81	81	65	58	50
1896	49	53	57	69	76	79	81	82	77	68	62	51
1897	48	55	66	66	71	81	82	80	78	71	60	54
1898	55	53	63	62	75	80	81	80	78	65	56	49
Average	51	54	59	67	73	79	81	80	78	67	58	53

OAKLAND.

Monthly Typhoid Deaths.

Obtained, in correspondence, by courtesy of Local Department of Health.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1889	1	1	4	2	2	0	0	1	1	3	3	1
1890	2	0	5	1	0	1	2	1	2	3	2	3
1891	0	0	0	2	2	1	3	4	6	2	3	3
1892	0	2	1	2	3	1	1	2	0	5	1	2
1893	0	2	0	0	1	4	22	4	7	2	3	1
1894	1	2	3	1	0	1	2	2	0	1	0	1
1895	2	3	0	3	2	0	3	1	2	0	1	1
1896	1	3	1	0	1	2	0	0	2	3	3	2
1897	1	1	0	0	1	0	1	0	2	1	1	1
1898	0	0	0	0	2	1	3	2	1	1	1	1
Average	0.8	1.4	1.4	1.1	1.4	1.1	3.7	1.7	2.3	2.1	1.8	1.6
Ratio of 100	3.9	6.9	6.9	5.4	6.9	5.4	18.1	8.3	11.3	10.3	8.8	7.8

Mean Monthly Temperature.

From "Monthly Weather Review," U. S. Weather Bureau.

Year	J.	F.	M.	A.	M.	J.	J.	A.	S.	O	N.	D.
1889	48	50	57	59	59	61	60	61	63	61	57	50
1890	44	48	54	55	60	59	62	62	61	62	57	49
1891	51	49	53	53	55	60	61	63	62	59	57	49
1892	52	50	53	53	58	62	64	64	63	58	53	49
1893	49	51	54	56	58	62	62	61	62	58	54	51
1894	45	48	52	57	59	61	59	61	62	59	56	49
1895	47	52	51	56	59	60	63	59	62	56	54	47
1896	51	53	55	54	58	61	64	63	—	58	51	49
1897	46	49	49	59	61	64	63	61	63	58	51	47
1898	44	51	51	57	57	64	62	62	61	60	53	47
Average	48	50	53	56	58	61	62	62	62	59	54	49

DRESDEN.

MONTHLY TYPHOID DEATHS.

From "Veröffentlichungen des Kaiserlichen Gesundheitsamtes."

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1888	4	2	2	1	1	0	0	6	4	1	2	3
1889	4	2	0	1	3	1	2	4	1	2	1	0
1890	1	3	4	0	1	1	1	2	1	3	3	2
1891	3	1	3	1	2	2	2	3	3	0	5	2
1892	0	0	4	1	0	1	2	1	1	3	1	2
1893	1	0	1	3	1	0	0	0	1	1	3	2
1894	0	0	1	8	3	2	1	3	5	1	2	0
1895	1	1	0	0	2	1	4	3	1	1	2	1
1896	0	0	0	4	2	2	1	1	0	1	1	3
1897	0	0	1	1	1	0	3	0	2	1	2	1
Average	1.4	.9	1.6	2.0	1.6	1.0	1.6	2.3	1.9	1.4	2.2	1.6
Ratio of 100	7.2	4.6	8.2	10.3	8.2	5.1	8.2	11.8	9.7	7.2	11.3	8.2

MEAN MONTHLY TEMPERATURE. AVERAGE 1864–1890.

From "Amtliche Publication des Königl. sächsischen meteorologischen Institutes. Das Klima des Königreiches Sachsen." Heft III, 1895.

	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
Centigrade	0	1	3	8	13	16	18	17	14	9	4	0
Fahrenheit	32	34	37	46	55	61	64	63	57	48	39	32

MUNICH.

Monthly Typhoid Deaths.

From "Veröffentlichungen des Kaiserlichen Gesundheitsamtes."

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1888	4	1	5	3	3	4	3	0	2	2	2	2
1889	3	2	2	2	3	2	6	1	1	6	2	1
1890	2	1	3	2	2	0	2	4	2	5	4	1
1891	2	3	3	3	2	3	1	1	1	3	0	2
1892	2	1	0	0	1	3	0	1	2	0	1	0
1893	3	3	0	1	1	20	15	9	1	3	1	0
1894	0	0	1	2	0	1	3	0	2	0	0	1
1895	1	2	1	0	0	1	0	2	3	1	0	4
1896	2	2	0	1	1	0	1	3	0	2	1	1
1897	0	0	0	2	1	7	7	5	1	0	0	0
Average	1.9	1.5	1.5	1.6	1.4	4.1	3.8	2.6	1.5	2.2	1.1	1.2
Ratio of 100	7.8	6.1	6.1	6.6	5.7	16.7	15.6	10.7	6.1	9.0	4.5	4.9

Mean Monthly Temperature.

From "Beobachtungen der meteorologischen Stationen im Königreich Bayern."

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1889	–4	–3	–1	7	15	18	17	16	11	8	1	–4
1890	1	–5	3	7	14	14	16	17	12	6	2	–7
1891	–6	–3	3	5	13	16	17	15	13	9	1	–7
1892	–2	1	1	7	13	16	16	19	14	7	3	–3
1893	–9	2	4	9	12	16	18	17	13	9	1	–3
1894	–5	1	4	10	11	14	18	16	11	8	3	–1
1895	–5	–8	1	8	11	15	18	17	16	7	5	0
Average	–4	–2	2	8	13	16	17	17	13	8	2	–3
Fahrenheit	25	28	36	46	55	61	63	63	55	46	36	27

VIENNA.

MONTHLY TYPHOID DEATHS.

From "Veröffentlichungen des Kaiserlichen Gesundheitsamtes."

Year.	J.	F.	M	A.	M.	J.	J.	A.	S.	O.	N.	D.
1888	7	7	12	8	7	9	4	4	5	9	5	26
1889	18	14	9	9	12	5	5	5	5	9	2	8
1890	6	7	7	7	6	6	4	6	11	7	3	7
1894	7	5	8	5	8	10	3	12	2	5	4	5
1895	5	3	2	2	5	6	13	12	6	11	14	7
Average	8.6	7.2	7.6	6.2	7.6	7.2	5.8	7.8	5.8	8.2	5.6	10.6
Ratio of 100	9.8	8.2	8.6	7.0	8.6	8.2	6.6	8.8	6.6	9.3	6.3	12.0

MEAN MONTHLY TEMPERATURE.

From "Jahrbücher der k. k. Central-Anstalt für Meteorologie und Erdmagnetismus."

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1888	—3	—3	4	8	15	18	18	18	15	8	2	0
1889	—2	—1	1	9	18	20	19	18	12	11	3	—4
1890	1	—2	6	9	16	16	19	21	14	9	4	—5
1891	—6	—2	4	7	16	17	18	17	16	12	3	1
1892	—1	1	2	10	14	17	19	21	16	9	2	—2
1893	—8	2	6	10	14	17	19	19	15	11	3	1
1894	—3	2	8	15	17	18	23	20	16	12	5	1
Average	—3	0	4	10	16	18	19	19	15	10	3	—1
Fahrenheit	27	32	39	50	61	64	66	66	59	50	37	30

CHICAGO.

Monthly Typhoid Deaths.

From Reports, Local Department of Health.

Year.	J.	F.	M.	A.	M.	J.	J	A.	S.	O.	N.	D.
1889	30	21	15	12	16	18	29	64	77	68	68	35
1890	53	136	103	45	82	107	86	115	95	72	67	47
1891	67	61	71	136	408	167	200	182	198	171	150	186
1892	311	187	76	56	70	55	211	179	138	92	67	47
1893	41	30	41	58	56	60	55	76	86	81	43	43
1894	46	26	27	30	31	31	37	52	71	68	38	34
1895	30	21	26	30	30	18	36	59	76	90	60	42
1896	87	89	65	33	31	44	58	64	87	89	60	44
1897	38	46	41	19	13	23	27	42	48	61	44	35
1898	29	32	41	94	67	35	55	45	65	62	56	55
Average	75	59	51	51	80	56	79	88	94	85	65	57
Ratio of 100	8.8	7.0	6.0	6.0	9.5	6.7	9.4	10.5	11.2	10.1	7.7	6.8

Mean Monthly Temperature.

From "Monthly Weather Review," U. S. Weather Bureau.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1888	15	23	30	45	53	67	72	69	60	48	41	31
1889	29	20	38	47	57	62	70	71	63	49	39	41
1890	31	32	29	46	53	70	72	68	60	51	42	31
1891	30	29	31	47	53	66	67	69	69	53	34	35
1892	19	30	31	44	52	64	72	71	64	54	35	23
1893	12	21	33	44	52	68	74	70	64	53	36	25
1894	27	23	41	47	56	71	73	71	66	52	34	32
1895	18	17	32	46	59	70	70	72	69	46	36	30
1896	27	27	31	53	65	67	72	73	61	50	38	33
1897	22	29	35	46	55	65	74	69	69	58	39	25
Average	23	25	33	46	55	67	72	70	64	51	37	32

PHILADELPHIA.

MONTHLY TYPHOID DEATHS.

From Reports, Local Department of Health.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1888	63	46	40	37	84	49	62	169	100	67	36	32
1889	62	79	61	41	64	50	68	83	70	63	33	66
1890	126	54	52	52	51	36	56	62	57	47	39	34
1891	50	44	102	141	76	42	49	42	53	35	23	26
1892	51	68	51	37	30	24	20	40	44	37	11	27
1893	43	34	38	35	61	37	26	47	47	29	25	35
1894	43	18	20	25	36	24	29	50	34	31	29	31
1895	36	64	48	40	39	38	33	36	32	43	30	30
1896	34	23	21	40	46	27	31	38	34	17	28	63
1897	36	18	27	41	50	32	25	49	24	20	31	48
Average	54	45	46	49	54	36	40	62	49	39	28	39
Ratio of 100	10.0	8.2	8.4	9.0	10.0	6.7	7.4	11.5	9.0	7.2	5.2	7.2

MEAN MONTHLY TEMPERATURE.

From "Monthly Weather Review," U. S. Weather Bureau.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1888	28	34	35	51	61	73	72	74	64	50	46	36
1889	39	29	42	53	65	71	75	73	66	53	47	44
1890	42	41	39	52	63	74	75	74	67	55	46	32
1891	36	40	38	54	61	72	72	74	72	55	44	43
1892	31	35	36	51	62	74	77	76	67	56	44	33
1893	24	32	39	51	61	72	77	76	66	58	44	36
1894	37	32	47	51	64	73	78	73	70	57	42	37
1895	31	25	38	52	62	74	73	77	72	53	47	39
1896	31	34	36	55	67	70	78	77	68	54	50	35
1897	31	36	43	53	63	69	76	74	68	58	46	38
Average	33	34	39	52	63	72	75	75	68	55	46	37

NEWARK.

MONTHLY TYPHOID CASES.

From Report of Local Department of Health for 1899.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1890	93	23	21	17	16	7	20	10	22	27	34	57
1891	88	42	43	18	18	11	15	167	207	137	92	38
1892	36	27	19	11	4	4	16	32	30	17	16	17
1893	5	3	9	6	8	10	11	26	12	21	7	7
1894	2	4	6	9	6	3	3	10	13	21	6	5
1895	2	3	2	1	6	4	4	31	38	21	21	15
1896	10	5	3	2	3	6	4	14	25	29	7	8
1897	5	5	11	7	5	2	8	7	14	11	13	15
1898	5	3	2	3	3	7	6	38	59	29	16	8
1899	2	2	301	67	27	9	19	28	30	12	10	8
Average	24.8	11.7	41.7	14.1	9.6	6.3	10.6	36.3	45.0	32.5	22.2	17.8
Ratio of 100	9.2	4.3	15.4	5.2	3.6	2.3	3.9	13.4	16.7	12.0	8.2	6.6

MEAN MONTHLY TEMPERATURE.

From "Monthly Weather Review," U. S. Weather Bureau.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1890	39	38	36	49	60	71	73	72	65	54	43	30
1891	33	36	36	51	59	69	70	72	69	53	43	41
1892	30	34	34	49	59	72	74	73	64	54	41	30
1893	22	28	35	47	59	68	74	73	62	55	41	34
1894	33	28	43	49	60	70	75	71	67	54	40	35
1895	29	25	36	48	61	71	71	74	70	50	45	37
1896	29	31	33	53	66	69	76	75	66	53	49	32
1897	30	33	40	50	62	67	75	72	66	55	44	35
1898	33	33	45	48	58	71	76	76	70	56	43	32
1899	29	25	36	49	61	72	74	72	64	56	43	34
Average	31	31	37	49	60	70	74	73	66	54	43	34

PARIS.

MONTHLY TYPHOID DEATHS.

From "Annuaire statistique de la ville de Paris."

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1888	146	78	52	58	54	52	81	51	70	65	69	71
1889	69	62	57	43	53	71	102	153	120	92	84	208
1890	74	39	45	47	51	57	44	54	76	92	71	73
1891	65	59	53	47	36	30	37	43	40	39	54	46
1892	50	36	48	37	48	78	90	89	97	105	62	59
1893	48	49	50	47	29	29	63	73	72	48	33	29
1894	25	53	289	84	34	46	33	37	21	22	29	24
1895	11	9	13	21	13	25	22	30	43	34	24	26
1896	35	17	21	10	25	9	30	35	26	17	28	9
Average	52	40	63	39	34	40	50	56	56	51	45	54
Ratio of 100	9.0	6.9	10.9	6.7	5.9	6.9	8.6	9.7	9.7	8.8	7.7	9.3

MEAN MONTHLY TEMPERATURE.

From "Annuaire statistique de la ville de Paris."

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1888	1	0	4	7	13	16	16	16	15	8	8	3
1889	1	2	4	9	15	19	18	17	14	10	6	0
1890	6	2	6	9	14	15	16	17	15	9	6	—3
1891	—1	3	6	8	12	16	17	16	15	12	5	5
1892	2	4	4	10	15	17	18	19	15	9	8	1
1893	—1	6	9	14	14	18	19	20	15	11	5	3
1894	3	5	8	12	12	16	18	17	14	10	7	4
1895	0	—4	5	11	14	16	18	18	19	9	9	5
1896	2	3	9	9	13	17	19	16	15	9	3	4
Average	1	2	5	9	13	16	17	17	15	9	6	2
Fahrenheit	34	36	41	48	55	61	63	63	59	48	43	36

NEW ORLEANS.

Monthly Typhoid Deaths.

From Reports, Local Department of Health.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1886	5	3	0	0	2	3	4	3	3	3	1	3
1887	2	4	0	1	3	4	1	4	2	4	2	7
1890	7	6	3	2	3	6	7	4	2	3	1	6
1891	5	1	1	1	3	6	7	6	10	2	4	13
1892	4	1	1	2	2	6	3	10	10	2	5	5
1893	2	2	5	1	1	6	4	1	4	4	4	5
1896	7	2	7	8	4	12	9	14	8	4	4	11
1897	10	4	3	7	6	16	21	18	10	11	19	16
Average	5.2	2.9	2.5	2.7	3.0	7.4	7.0	7.5	6.1	4.1	5.0	8.2
Ratio of 100	8.5	4.7	4.0	4.5	4.9	11.9	11.3	12.2	9.9	6.7	8.1	13.4

Mean Monthly Temperature.

From "Monthly Weather Review," U. S. Weather Bureau.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1888	56	59	60	70	73	77	81	78	75	68	59	51
1889	53	53	61	70	74	78	83	81	79	70	59	64
1890	65	64	62	70	74	81	82	81	78	69	64	56
1891	53	63	61	68	74	81	81	81	78	68	60	56
1892	49	61	59	69	74	79	80	82	77	71	62	56
1893	50	61	61	72	76	80	83	82	80	69	60	58
1894	58	55	63	71	75	78	79	80	80	71	60	58
1895	52	45	62	68	74	80	82	82	82	69	60	54
1896	52	56	61	71	78	80	83	83	79	70	65	55
1897	51	58	69	68	74	82	84	82	79	74	64	57
Average	54	57	62	70	75	80	82	81	79	70	61	56

ATLANTA.

Monthly Typhoid Deaths.

Obtained, in correspondence, by courtesy of Local Board of Health.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D
1893	1	1	3	3	4	5	11	13	7	9	5	1
1894	0	0	1	1	3	6	11	12	7	6	2	1
1895	0	0	3	0	1	3	4	12	14	20	6	5
1896	3	2	4	2	3	7	13	8	10	8	5	3
1897	1	0	0	1	0	10	10	11	9	6	4	3
1898	4	3	1	4	4	5	5	8	8	7	5	2
Average	1.5	1.0	2.0	1.8	2.5	6.0	9.0	10.7	9.2	9.3	4.5	2.5
Ratio of 100	2.5	1.7	3.3	3.0	4.2	10.0	15.0	17.8	15.3	15.5	7.5	4.2

Monthly Temperature.

From "Monthly Weather Review," U. S. Weather Bureau.

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1893	36	46	51	64	67	74	81	77	73	62	51	47
1894	47	45	57	62	69	76	76	76	73	62	49	46
1895	40	34	51	60	67	77	77	77	76	60	52	44
1896	42	45	49	66	75	75	78	80	75	61	56	44
1897	39	48	55	60	68	79	78	76	74	66	53	45
1898	47	43	57	56	73	79	78	77	74	60	49	44
Average	42	43	53	61	70	77	78	77	74	62	52	45

CHARLESTON.

Monthly Typhoid Deaths.

From Reports, Local Department of Health.

Year.	J.	F.	M.	A.	M	J.	J.	A.	S.	O.	N.	D.
1888	3	3	1	0	1	2	2	7	4	5	4	4
1889	3	2	2	4	1	4	3	5	3	5	3	5
1890	4	6	3	2	2	6	6	8	4	9	2	4
1891	5	2	1	0	0	1	6	3	3	5	2	0
1892	5	1	2	1	4	0	3	3	3	3	1	1
1893	1	4	2	0	2	1	4	2	4	3	1	0
1894	1	2	2	2	1	4	1	2	4	4	2	0
1895	1	0	2	1	2	2	10	3	2	5	3	2
1896	3	5	3	3	2	6	4	5	4	3	1	5
1897	1	2	2	4	0	3	5	5	7	1	3	7
Average	2.7	2.7	2.0	1.7	1.5	2.9	4.4	4.3	3.8	4.3	2.2	2.8
Ratio of 100	7.6	7.6	5.7	4.8	4.2	8.2	12.5	12.2	10.8	12.2	6.2	7.9

Mean Monthly Temperature.

From "Monthly Weather Review," U. S. Weather Bureau.

Year.	J	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1888	51	54	55	66	72	78	78	80	74	64	56	47
1889	52	47	55	63	74	77	81	78	76	65	60	60
1890	59	61	56	65	73	82	80	80	76	68	62	51
1891	50	58	55	65	70	80	80	81	76	64	56	55
1892	48	53	55	64	72	78	80	81	75	66	57	52
1893	43	56	56	68	72	78	83	79	78	68	58	54
1894	53	53	61	65	72	77	79	80	78	68	57	52
1895	49	41	56	64	70	79	81	82	78	66	58	51
1896	48	52	55	66	77	79	82	81	77	67	63	49
1897	47	55	61	66	72	80	82	81	75	70	62	54
Average	50	53	57	65	72	79	81	80	76	67	59	53

EMPIRE OF INDIA.

MONTHLY TYPHOID ADMISSIONS, BRITISH TROOPS IN INDIA.

From Report on Sanitary Measures in India in 1896–97. Vol. XXX.

Period.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1886–95 1896	518 65	418 75	689 202	1427 214	1795 160	1365 152	1441 175	1718 214	1400 179	923 90	745 92	879 177
Total	583	493	891	1641	1955	1517	1616	1932	1579	1013	837	1056
Average Ratio of 100	53 3.9	45 3.3	81 5.9	149 10.9	178 13.0	138 10.1	147 10.7	175 12.8	144 10.5	92 6.7	76 5.5	96 7.0

MONTHLY RANGE OF TEMPERATURE.

From "Handbuch der Klimatologie," J. Hann. Zweite Auflage. Stuttgart, 1897.

Difference between the monthly mean and the yearly mean. Central India, Deccan, 20.8° N., 78.0° E., 390 M.

J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
–6	–3	2	6	8	3	0	0	0	0	–4	–7

Punjab, 31.1° N., 72.3° E., 200 M.

J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
–12	–10	–3	3	7	10	9	7	6	0	–7	–11

SANTIAGO DE CHILE.

Typhoid cases received at Hospital S. Francisco de Borja and Hospital S. Juan de Dios, 1886–1895.

Figures from essay, "La Fiebre Tifoidea en Santiago," by Pedro V. Garcia, P., "Revista Chilena de Hijiene." Tomo III, Núm. 11.

	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
Total	121	121	102	87	65	49	52	47	49	60	73	107
Ratio of 100	13.0	13.0	11.0	9.4	7.0	5.3	5.6	5.1	5.3	6.5	7.8	11.5

MEAN MONTHLY TEMPERATURE.

From "Observaciones meteorolójicas hechas en el Observatorio Astronómico de Santiago."

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1882	20.7	18.9	16.4	12.6	10.3	8.0	7.4	9.5	12.4	15.2	16.6	18.4
1883	19.1	18.9	15.3	12.8	9.9	7.5	6.8	8.9	10.8	13.3	16.2	18.9
1884	21.7	18.2	15.3	13.3	9.0	7.0	6.4	10.3	10.9	13.2	16.4	19.0
1885	18.7	18.3	16.4	10.3	8.8	7.5	6.4	9.4	12.6	13.5	18.0	17.4
1886	19.9	18.1	16.5	13.4	10.2	6.2	8.1	8.7	11.5	14.4	16.5	19.4
1887	19.8	18.4	16.4	13.1	9.7	8.5	8.6	10.5	11.7	13.4	16.0	18.1
Average	20	18	16	13	10	7	7	9	12	14	16	18
Fahrenheit	68	64	61	55	50	45	45	48	54	57	61	64

BUENOS AYRES.

MONTHLY TYPHOID DEATHS, 1876–1897.

	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
Total	573	534	632	728	642	487	317	284	233	262	317	432
Ratio of 100	10.4	9.8	11.6	13.4	11.8	9.0	5.8	5.2	4.3	4.8	5.8	7.9

MEAN MONTHLY TEMPERATURE, 1876–1897.

Figures from essay, "La Fiebre Tifoidea en Buenos Aires," by Dr. Diego T. R. Davison, "Anales del Departamento Nacional de Hijiene." Año VIII. Núm. 13.

	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
Centigrade	23.5	22.8	21.2	16.7	13.2	10.3	10.4	11.5	13.3	16.1	19.8	22.4
Fahrenheit	73	73	70	63	55	50	50	53	55	61	68	72

III. INTERPRETATION OF THE STATISTICAL RESULTS.

An examination of the curves plotted as above described shows that a very striking parallelism exists between the monthly variations in temperature and typhoid prevalence. Of the thirty communities considered, eighteen show this parallelism to be almost perfect; these are the Empire of Japan, the States of New York and Massachusetts, the District of Columbia, and the cities of Atlanta, Baltimore, Berlin, Boston, Buenos Ayres, Denver, Leipsic, London, Mobile, Montreal, New York, St. Paul, San Francisco, and Santiago. Three other typhoid curves — those for India, for Charleston, and for New Orleans — rise with the temperature in spring, and fall with it in autumn, but show a temporary decrease in the disease during the time of greatest heat. In all these twenty-one cases the connection between the two factors seems too close not to indicate a vital relation. In the northern cities — Montreal, Boston, Denver, and St. Paul — the curve of typhoid is acute; in cities with a more and more equable temperature the curve of the disease is progressively flattened, the limit being reached in the case of San Francisco. In the northerly localities the maximum occurs in September and October; in the southern cities, with a milder winter, it comes in August (Atlanta) or July (Charleston and Mobile). In the two cities of the southern hemisphere the curves of both typhoid fever and temperature are exactly reversed. In the case of the tropical and sub-tropical regions — India, Charleston, and New Orleans — it appears that the rise with the temperature, after beginning in the usual fashion, is checked by some other factor, perhaps strong sunlight or extreme dryness. (See Plates I.–VIII.)

It remains now to consider the nine cities which show more or less irregular curves, and to see if their abnormalities are capable of explanation. These nine cities are Chicago, Cincinnati, Dresden, Munich, Newark, Oakland, Paris, Philadelphia, and Vienna. The first thing to notice in this connection, and the one all previous students of seasonal variation have neglected is the necessity of discriminating between sharp epidemic outbreaks of the disease and the slow succession of isolated cases which characterize that condition known to the older sanitarians as "endemic." The term endemic has been so misused and has become so associated with the idea of a mysterious miasm inherent in a geographical region, that it cannot be safely used in a more scientific sense. At the same time a distinction, vital to the epidemiologist, must be drawn between the infection which reaches a number of persons at once through a single medium as water or milk, and the slower, more complex process by which a disease passes from person to person through a population, the path of the contagious material being different in each individual instance. For this sort of infection which spreads gradually in a community instead of striking a large number of persons at a single blow, the term "prosodemic," meaning "through" or "among" the people, has been suggested.

In the examination of data bearing on the question of the seasonal prevalence of typhoid fever it is obviously the prosodemic disease which should be mainly considered. Cases of this sort furnish a large number of independent facts which may be averaged together fairly; while an epidemic must always be a perturbing element. Thus, for example, a public water supply furnishes exceptional facilities for the distribution of infection from its watershed to a large number of individuals. Twelve hundred cases of typhoid fever at Plymouth, Pa., derived from a single house on the banks of a reservoir have, for a study of normal seasonal variations, far less significance than fifty cases, in which the paths of infection are separate and independent.

Curves of seasonal variation which are based on a small number of cases will always be liable to show irregularities due to single epidemics; and if our tables of typhoid deaths be inspected, it will at once be seen that four of the nine exceptions to a regular seasonal distribution are due to this cause. Thus the form of the Oakland curve is distorted by the epidemic of twenty-two deaths in July, 1893, which we are informed by the local authorities was due to an infection of the milk supply. The largest number of deaths in any other month in the ten years was seven, so that this irregularity could not be compensated. Similarly, the Munich curve owes its peculiarity to the epidemic of thirty-five deaths in June and July of 1893, the largest number in any other month being nine. The curve for Vienna is controlled, in a similar way, by an epidemic in December, 1888, and January and February, 1889. In all these cases the curve would follow the temperature more or less normally if these perturbations were eliminated. Again for Dresden the total number of deaths is so small that eight cases in April, 1894, cause a notable distortion. That the typhoid in this city did follow the temperature when there was enough of it to give average results is shown by Fiedler's figures for 1850–60, quoted above.

We may thus consider that the irregularities of the Oakland, Munich, Vienna, and Dresden curves are explained by the fact that the number of cases considered is too small to eliminate the haphazard effect of epidemics. There remain to be explained the exceptions offered by Chicago, Cincinnati, Newark, Paris, and Philadelphia, in all of which cities the amount of material is amply sufficient to prevent mere chance irregularities. If the curves for these five cities be compared, it will at once be noted that they exhibit a remarkable resemblance. Besides the summer rise, each curve exhibits two secondary maxima, one in December or January, the other between March and May. If our general theory be correct, there must in these localities be some special condition tending to produce typhoid epidemics in the early winter and the early spring, which modifies the normal influence of the season. Fortunately, we know exactly what this influence is. These five cities — and of the thirty communities we have considered, these five only — draw their water supply from surface sources liable to gross pollution. The epidemics of March, 1899, at Newark; of May, 1891, at Chicago; of January, 1888, and December, 1889, at Paris, as well as the lesser winter and spring outbreaks in other years, were unquestionably due to the public water supplies of those cities. We have here then a special condition influencing the occurrence of epidemics in cities having surface water supplies and therefore deranging the normal course of prosodemic typhoid. The heavy autumn rains and the spring floods consequent on the melting of the winter's snow, carry into surface water supplies a larger amount of pollution than reaches them at any other time, — as is well shown by a comparison of the bacterial content of surface water at various seasons. We may venture to generalize by saying that winter and spring epidemics are characteristic of those cities whose water-supply is most subject to pollution; they are absent from communities which use filtered water or water obtained from adequately protected watersheds.

Finally, then, it appears that of the thirty communities we have studied, all but four, in which the number of cases is too small to furnish average results, give typhoid curves corresponding to one of three types, — the normal temperature distribution, the subtropical modification, and the modification due to winter and spring water-epidemics. These latter types of distribution are explicable as the resultant of a combination of the temperature factor with another. We may therefore conclude that wherever a sufficient number of cases has been considered a direct relation between typhoid fever and temperature appears to be general and invariable.

IV. CONCLUSION OF THE AUTHORS THAT THE SEASONAL PREVALENCE OF TYPHOID FEVER DEPENDS MAINLY UPON SEASONAL TEMPERATURE.

The increase of typhoid fever with a gradual rise in the mean air temperature of a given locality appears to be a phenomenon so widespread and significant as to indicate beyond reasonable doubt some relation between the two factors. Whether this relation be direct or indirect must be determined by considerations as to the ætiology of the disease and as to the relation of temperature to the various vehicles mainly concerned in its transmission.

The methods by which prosodemic typhoid may spread are almost innumerable. The last link in the chain is, in most cases, some article of food or drink, and the food becomes infected, in many instances, from the fingers of a typhoid patient or of his unprofessional attendants. The transmission of typhoid fever on a large scale by water and milk has led sanitarians to minimize unduly this direct personal element in its ætiology. In a well-organized, thoroughly sanitary city dwelling the distinction between contagion and infection is an important one; but in dirty surroundings typhoid becomes, for all practical purposes, a contagious disease. This fact, in itself, throws some little light on its seasonal prevalence. A large number of persons who live ordinarily in cities, surrounded by many sanitary safeguards, in vacation time are exposed in camps and summer resorts to abundant opportunities for filth infection. The autumn fever, in small part at least, occurs among those who are attacked on such summer vacations or immediately after their return home.

Again, several special sources of food contamination have a more potent influence at this season of the year. Those observers are perhaps correct who consider that ground waters are most dangerous when the wells are at their lowest and liable to receive impurities from a wide area. Professor Gualdi would explain the facts by attaching great significance to raw vegetables as vehicles for the transmission of typhoid fever; and he has traced out a more or less close connection between the consumption of these articles and the amount of typhoid in Rome. Most original of all is the suggestion of Bonne, who seeks to explain the autumnal maximum at Hamburg by the increased amount of bathing in the Elbe beginning with the July heat.

Of the three great intermediaries of typhoid transmission, fingers, food, and flies, the last is even more significant than the others in relation to seasonal variation. Since the emphasis laid on this vehicle of infection by the surgeons who studied the conditions of the late Spanish War, our conception of its importance has grown more and more considerable. There can be little doubt that many of the so-called "sporadic" cases of typhoid fever which are so difficult for the sanitarian to explain are conditioned by the passage of a fly from an infected vault to an unprotected table or an open larder. The relation of this factor to the season is of course close and complete; and a certain amount of the autumnal excess of fever is undoubtedly traceable to the presence of large numbers of flies and to the opportunities for their pernicious activity.

None of the factors noted, however, nor the whole of them taken together, seem to us to account satisfactorily for the observed phenomena. Neither the agency of insects, nor the exposure of urban subjects to rural unsanitary conditions, though both are undoubtedly important, can be held to account for a phenomenon so constant, so striking, and so universal. The parallelism between the curves of typhoid and of temperature is too close not to suggest in the strongest manner some direct relation such as was postulated by Murchison, Liebermeister, and Davidson. No one doubts a direct correlation between the growth in a wheat-field and the changes of temperature during the changing seasons. The fundamental properties of protoplasm are so constant that there seems no reason to doubt a similar favorable effect of the warmth of summer, not on the crop of typhoid plants growing in human bodies, but on the survival seed which passes from one body to another through the environment. This is theoretical; but the experiments reported in the first section of this paper furnish practical evidence to confirm the *à priori* hypothesis that it must be more difficult for an organism habituated to a temperature of 98° F. to persist in Nature when the thermometer is at 30° than when it is in the neighborhood of 80°.

We do not wish to assert that the typhoid bacillus multiplies in the environment during the summer months of a temperate climate. It is the absence of the destructive influence of cold, rather than any stimulating influence of heat, which permits the rise culminating in the autumnal maximum.

In fine, the probable mechanism of the seasonal changes according to our conception is as follows: —

The bacteriology and the ætiology of typhoid fever both indicate that its causal agents cannot be abundant in the environment during the colder season of the year. The germs of the disease are carried over the winter in the bodies of a few patients and perhaps in vaults or other deposits of organic matter where they are protected from the severity of the season. The number of persons who receive infection from the discharge of these winter cases will depend, other things being equal, upon the length of time for which the bacteria cast in these discharges into the environment, remain alive and virulent. The length of the period during which the microbes live will depend largely upon the general temperature; as the season grows milder, more and more of each crop of germs sent at random into the outer world will survive long enough to gain entry to a human being and bear fruit. The process will be cumulative. Each case will cause more secondary cases; and each of the latter will have a still more extensive opportunity for widespread damage. In our opinion the most reasonable explanation of the seasonal variations of typhoid fever is a direct effect of temperature upon the persistence in Nature of germs which proceed from previous victims of the disease.

4

PART III.

BIBLIOGRAPHY.

A. ON DISEASE ATTRIBUTED TO POLLUTED ICE AND ICE-CREAM.

1. **Nichols, A. H.** Report on an Outbreak of Intestinal Disorder attributable to the Contamination of Drinking Water by Means of Impure Ice. Seventh Ann. Report, S. B. H., Mass., 1876, p. 467.
2. **Smart, Charles.** On Mountain Fever and Malarious Waters. Am. Journ. Med. Sci., Jan. 1878, p. 17.
3. **Sickness from Impure Ice.** Second Ann. Report, S. B. H., Conn., 1879, p. 90.
4. **Chamberlain, C. W.** Impure Ice. Fifth Ann. Report, S. B. H., Conn., 1882, p. 295.
5. **Duclaux.** Les Impuretés de la glace. Ann. d'Hyg., 1884, 3rd series, XII, p. 97.
6. **Riche, A.** Emploi de la glace dans l'alimentation. Ann. d'Hyg., 1893, 3rd series, XXX, p. 47.
7. **Dorange.** Epidémie de fièvre typhoide due à l'ingestion de glace impure. Rev. d'Hyg. at de Police Sanitaire, XX, 4, 1898, p. 295.
8. **Turner, G.** Report on an Epidemic of Enteric Fever due to the Consumption of Ice-Cream. Practitioner, London, 1892, XLIX, p. 141.
9. **Munro, A. C.** Epidemic of Enteric Fever, traceable to Infected Ice-Creams and Water-Supply and attacking over Eight Hundred Persons. Public Health, London, 1894–95, VII, p. 30.
10. **Vaughan, V. C., and Perkins, G. D.** Ein in Eiscrême und Käse gefundener giftproducirender Bacillus. Arch. f. Hyg., 1896, XXVII, p. 308.
11. **Hope.** Ice-Cream as a Vehicle of Infection in Typhoid Fever. Liverpool M.-Chir. J., 1898, XVIII, p. 185.
12. **Taylor, L. H.** Report upon the Epidemic of Typhoid Fever at Plymouth, Pennsylvania. First Ann. Report State Board of Health, Penn., 1885, p. 176.

B. ON THE BACTERIOLOGY OF NATURAL ICE, SNOW AND HAIL, AND OF ICE-CREAM.

13. **Sanderson, J. B.** The Origin and Distribution of Microzymes (Bacteria), in Water, etc. Quar. Jour. Mic. Sci., XI, 1871, p. 323.
14. **Cohn, F.** Untersuchungen über Bakterien. Beiträge zur Biologie der Pflanzen, Band I, 1875, II, p. 220.
15. **Leidy, J.** Organisms in Ice. Proc. Acad. Nat. Sci., Phila., 1884, p. 260.
16. **Pohl.** (Chemical and bacteriological investigations in relation to the water-supply of St. Petersburg.) Wratsch, 1884, No. 9.
17. **Gardiner, J. T.** Report on the Purity of Ice from Onondaga Lake, the Erie Canal at Syracuse, and from Cazenovia Lake. Report to the State Board of Health of New York, July, 1886.
18. **Breunig, J.** Bakteriologische Untersuchung des Trinkwassers der Stadt Kiel. (Inaug. Dissertation.) Kiel, 1888. (Ref. Baumgarten's Jahresbericht, IV, p. 480.)
19. **Kowalski.** Ueber bakteriologische Wasseruntersuchungen. Wiener klinische Wochenschrift, 1888, Nos. 10, 11, 14, 15, and 16. (Ref. Centr. f. Bakt., IV, p. 467.)
20. **Heyroth.** Ueber den Reinlichkeitszustand des künstliches Eises. Arb. aus dem K. Gesundheitsamte, IV, 1888, p. 1.

21. **Report upon the Pollution of Ice Supplies.** Twenty-first Ann. Report, S. B. H., Mass., 1889, p. 143.
22. **Character and Quality of the Ice-Supply of London.** Lancet, Vol. LXXI, 1893, II, p. 269.
23. **Girard, C. et Bordas, F.** Analyses chimiques et bactériologiques des glaces consommées à Paris. Ann. d'Hyg., 1893, 3rd series, XXX, p. 78.
24. **Christomonas, A. C.** Ueber einige Eigenschaften des künstlichen Eises. Oesterr. chem. ztg., 1898, p. 486.
25. **Janowsky.** Ueber den Bakteriengehalt des Schnees. Wratsch, 1888, IX, p. 727. Also Centr. f. Bakt., IV, 1888, p. 547.
26. **Schmelck.** Eine Gletscherbakterie. Centr. f. Bakt., IV, 1888, p. 545.
27. **Schmelck.** Bakteriologische Untersuchungen des Trinkwassers in Christiania. Centr. f. Bakt., VIII, p. 102.
28. **Bujwid, O.** Die Bakterien im Hagelkörnern. Centr. f. Bakt., III, 1888, p. 1.
    Also Ann. de l'Inst. Past., 1887, I, p. 592.
29. **Foutin, W. M.** Bakteriologische Untersuchungen von Hagel. Wratsch, 1889, Nos. 49, 50. (Ref. Centr. f. Bakt., VII, 1890, p. 372.)
30. **Giacosa, P.** Studii sui germi di microrganismi nella neve delle alte montagne. Giornale della R. Accademia di medicina, 1890, Nos. 11–12.
31. **Abbott, A. C.** Bacteriological Study of Hail. Johns Hopkins Hospital Bulletin, 1890, Vol. I, No. 5, p. 56.
32. **Dominguez, S. e Calumbide.** Bacterias del hielo. Ann. asist. púb. Buenos Aires, 1891–2, II, pp. 213, 263.
33. **Scofone, L.** Esame batteriologico delle acque di neve di torrente e di lago. Arch. per le sc. med. de Torino, XX, 1895, n. 12.
34. **Scofone, L.** Esame batteriologico di neve e ghiaccio. Arch. per le sc. med. de Torino, 1897, XXI, p. 437.
35. **Harris, A. E.** Report to Chairman and Members of the Public Health Committee, Islington, 1894. (Ref. Lancet, LXXII, 1894, p. 862.)
36. **Nield-Cook, J.** The Bacteriology of Ice-Cream. Public Health, London, 1895–6, VIII, p. 252.
37. **Stevenson.** Bacteria in Ice-Cream. Food and Sanitation, April 16, 1898.
38. **Wilkinson, J.** Ice-Creams: their Manufacture and Bacteriology. Public Health, London, 1899, XI, p. 255.
39. **Nystrom, C.** Om făsnings och forruttnelseprocesserna pă Spetsbergen, Upsala, Lăkarefŏrenings fŏrhandlingar, t. IV.
40. **Couteaud.** Bactériologie de la zone glaciale. Arch. de méd. nav., 1893, LIX, p. 119.
41. **Levin.** Les microbes dans les régions arctiques. Ann. de l'Inst. Pasteur, XIII, 1899, p. 558.

C. ON THE EFFECT OF FREEZING AND OTHER LOW TEMPERATURES UPON BACTERIA.

42. **von Frisch, A.** Sitzungsber. der Wiener Akad. d. Wissenschaften, LXXV, p. 257.
43. **Pictet et Young.** De l'action du froid sur les microbes. Compt. rend. Acad. des Sc., XCVIII, 1884, p. 747.
44. **Finkler und Prior.** Forschungen über die Cholerabakterien. Bonn, 1885.
45. **McKendrick.** The Action of Cold on Microphytes. (Communication to Biological Section, British Association for the Advancement of Science.) Nature, XXXII, 1885, p. 561.
46. **Forster, J.** Ueber einige Eigenschaften leuchtender Bakterien. Centr. f. Bakt., 1887, II, p. 337.
47. **Fischer.** Bakterienwachsthum bei 0° C. Centr. f. Bakt., 1888, IV, p. 89.
48. **d'Arsonval, A.** Emploi de l'acide carbonique liquéfié pour la filtration et la stérilization rapides des liquides organiques. Compt. rend. Acad. des Sc., 1891, CXII, p. 667.

49. **Forster, J.** Ueber die Entwickelung von Bakterien bei niederen Temperaturen. Centr. f. Bakt., 1892, XII, p. 431.
50. **Fischer.** Deutsche medizinische Wochenschrift, 1893, No. 23.
51. **Pictet, R.** De l'emploi méthodique des basses températures en biologie. Archives des sciences physiques et naturelles de Genève, 3rd period, XXX, No. 10, p. 293.
52. **d'Arsonval et Charrin.** Influence des agents atmosphériques, en particulier de la lumière, du froid, sur le bacille pyocyanogène. Compt. rend Acad. des Sc., 1894, CXVIII, p. 151.
53. **Do.** Influence des agents cosmiques (électricité, pression, lumière, froid, ozone, etc.) sur l'évolution de la cellule bactérienne. Arch. de physiol. norm. et path, 1894, 5 s., VI, p. 335.
54. **Weber, A.** Zur Aetiologie der Krebspest. Arb. aus dem K. Gesundheitsamte, XV, 1899, Heft 2.
55. **Mason, W. P.** Examination of Water. New York, 1899, p. 117.
56. **Ravenel, M. P.** The Resistance of Bacteria to Cold. Medical News, Phila., June 10, 1899.
57. **Cadéac et Malet.** Recherches expérimentales sur la virulence des matières tuberculeuses desséchées, putrifiés ou congélées. Lyon Med., 1888, p. 229.
58. **Frankland, Grace and Percy.** Micro-Organisms in Water. London, 1894. p. 253.
59. **Kasansky, M. W.** Die Einwirkung der Winterkälte auf die Pest- und Diphtheriebacillen. Centr. f. Bakt., 1899, XXV, p. 122.
60. **Abel, R.** Versuche über das Verhalten der Diphtheriebacillen gegen die Einwirkung der Winterkälte. Centr. f. Bakt., 1895, XVII, p. 545.
61. **Seitz, C.** Bakteriologische Studien zur Typhus-Aetiologie. Munchen, 1886.
62. **Billings, J. S.** Sanitary Engineer, January 29, 1887, p. 211.
63. **Chantemesse et Widal.** Recherches sur le bacille typhique et l'étiologie de la fièvre typhoide. Arch. de Phys. norm. et path., 1887, p. 217.
64. **Bazhenoff.** (Effect of different agents on the typhoid bacilli of Ebert-Koch.) Ejened. klin. gaz. St. Petersburg, 1885, V, pp. 81, 95.
65. **Janowski.** Zur Biologie der Typhusbacillen, II. Centr. f. Bakt., VIII, 1890, p. 449.
66. **Remlinger, P.** Sur la sensibilité du bacille d'Eberth aux variations de température. Compt. rend. de la Société de Biologie, 1897, 9 juillet.
67. **Koch, R.** Deutsche medizinische Wochenschrift, 1884, No. 32.
68. **Raptschewski.** Wratsch, 1886, No. 5.
69. **Cornil et Babes.** Les bactéries. Paris, 1890. Vol. II, p. 183.
70. **Schruff.** Zum Sanitätsbericht über den Kreis Neuss für 1893. (Cit. by Weiss.)
71. **Finkelnburg.** Zur Frage der Variabilität der Cholerabacillen. Centr. f. Bakt., 1893, XIII, p. 114.
72. **Karschinski, W.** Archiv des Laboratoriums für Allg. Pathologie an der Universität zu Warschau, 1893.
73. **Renk.** Ueber das Verhalten der Cholerabacillen im Eise. Fortschritte der Med., 1893, p. 396.
74. **Uffelmann, J.** Weitere Beiträge zur Biologie der Cholerabacillen. Einfluss der Kälte auf ihre Lebensfahigkeit. Berliner klin. Wochenschr., 1893, p. 158.
75. **Wnukow, N.** Ueber den Einfluss längerer Einwirkung niedriger Temperaturen auf die Kochschen Komma-bacillen. Wratsch, 1893, No. 18.
76. **Montefusco, A.** Azione della basse temperature sulla virulenza degli spirilli del colera. Annali dell' Instituto d' igiene dell' Universita di Roma, 1893, III, p. 31.
77. **Abel.** (Ref.) Centr. f. Bakt., XIV, 1893, p. 184.
78. **Kasansky, M. W.** Ueber den Einfluss der Kälte auf die Cholerabakterien von Koch und ähnliche Vibrionen von Finkler-Prior, Miller, Deneke und die Vibrionen Metschnikoff. Centr. f. Bakt., 1895, XVII, p. 184.
79. **Weiss.** Ueber das Verhalten der Cholera-Erreger bei niedrigen Temperaturen. Zeit. f. Hyg., XVIII, 1894, p. 492.

D. ON THE QUANTITATIVE STUDIES OF THE DESTRUCTION OF BACTERIA BY FREEZING.

80. **Pengra, C. P.** Purification of Water by Freezing. Twelfth Ann. Report, S. B. H., Michigan, 1884. p. 79.
81. **Fränkel, C.** Ueber den Bakteriengehalt des Eises. Zeit. f. Hyg., I, 1886, p. 302.
82. **Wolffhuegel und Riedel.** Die Vermehrung der Bakterien im Wasser. Arb. aus dem K. Gesundheitsamte, Berlin, 1886, p. 455.
83. **Prudden, T. M.** On Bacteria in Ice and their Relations to Disease, with Special Reference to the Ice-Supply of New York City. The Medical Record, 1887, March 26 and April 2.
84. **Bordoni-Uffreduzzi.** Die Biologische Untersuchung des Eises in sein Beziehung zur öffentlichen Gesundheitspflege. Centr. f. Bakt., II, 1887, p. 489.
85. **Russell, H. L.** Preliminary Observations on the Bacteria in Ice from Lake Mendota, Madison, Wis. The Medical News, August 17, 1889.
86. **Mills, H. F.** Typhoid Fever in its Relation to Water Supplies. Twenty-second Ann. Report, S. B. H., Mass., 1890, p. 542.

E. ON THE SEASONAL PREVALENCE OF TYPHOID FEVER AND ITS RELATION TO SEASONAL TEMPERATURE.

87. **Bartlett, Elisha.** The History, Diagnosis, and Treatment of Typhoid and of Typhus Fever, 1842.
88. **Flint, A.** Clinical Reports on Continued Fever, Philadelphia, 1855.
89. **Griesinger.** Infektionskrankheiten. Vol. II, Abth. 2 of Virchow's Handbuch der speciellen Pathologie und Therapie. Erlangen, 1857, p. 122.
90. **Tweedie, A.** Lectures on Fevers. Lancet, 1860, Vol. I, p. 1.
91. **Haller.** Die Volkskrankheiten in ihrer Abhängigkeit von den Witterungsverhältnissen. Wien, 1860.
92. **Hirsch, A.** Handbuch der historisch-geographischen Pathologie. Erlangen, 1860. p. 177.
93. **Murchison, Charles.** A Treatise on the Continued Fevers of Great Britain. 1862.
94. **Fiedler.** Statistische Mittheilungen über Typhus abdominalis. Archiv der Heilkunde, III, 1862, p. 155.
95. **Buhl, L.** Ein Beitrag zur Aetiologie des Typhus. Zeit. f. Biol., I, 1865, p. 1.
96. **Seidel, L.** Ueber den numerischen Zusammenhang, welcher zwischen der Haüfigkeit der Typhus-Erkrankungen und dem Stande des Grundwassers während der letzten 9 Jahre in München hervorgetreten ist. Zeit. f. Biol., I, 1865, p. 221.
97. **Seidel, L.** Vergleichung der Schwankungen der Regenmengen mit den Schwankungen in der Haüfigkeit des Typhus in München. Zeit. f. Biol., II, 1866, p. 145.
98. **Liebermeister.** Zur Aetiologie des Abdominaltyphus. Deutsche Klinik., 1866, p. 89.
99. **v. Pettenkofer, M.** Ueber die Schwankungen der Typhussterblichkeit in München von 1850 bis 1867. Zeit. f. Biol., IV, 1868, p. 1.
100. **Socin, B.** Typhus, Regenmenge und Grundwasser in Basel. Basel, 1871.
101. **Virchow.** Ueber die Sterblichkeitsverhältnisse Berlins. Berliner klinische Wochenschrift, IX, 1872, p. 597.
102. **Murchison, C.** A Treatise on the Continued Fevers of Great Britain. Second Edition, London, 1873.
103. **Liebermeister, K.** Typhoid Fever. Ziemssen's Cyclopedia of the Practice of Medicine. (American Edition, edited by A. H. Buck, 1874).
104. **Cousot.** Étude sur la nature, l'étiologie, et le traitement de la fièvre typhoïde. 1874. p. 117.
105. **Oesterlen, F.** Handbuch der medicinischen Statistik. Tübingen, 1874.

106. **Buchan, A., and Mitchell, A.** The Influence of Weather on Mortality from different Diseases and at different Ages. Journ. Scot. Meteor. Soc., 1874–5, N. S., IV, p. 187.
107. **Sander, F.** Handbuch der öffentlichen Gesundheitspflege. Leipzig, 1877.
108. **Sixth Ann. Report, Secretary, State Board of Health of Michigan.** 1878. p. 293.
109. **Oldendorff, A.** Article, Morbiditäts- und Mortalitäts-Statistik, in Eulenburg's Real-Encyclopädie der gesammten Heilkunde, Vol. IX, 1881, p. 304.
110. **Fodor, J.** Deutsch. Viert. f. öff. Ges., VII, p. 205.
Hygienische Untersuchungen über Luft, Boden, und Wasser. Braunschweig, 1881–2.
111. **Welch, F. H.** Enteric Fever, Philadelphia, 1883.
112. **Hirsch, A.** Handbook of Geographical and Historical Pathology. Second Edition (translated by Creighton, London, 1883).
113. **Baker, H. B.** The Relation of the Depth of Water in Wells to the Causation of Typhoid Fever. Twelfth Annual Report S. B. H., Michigan, 1884, p. 89. (Am. P. H. Assoc., October 16, 1884.)
114. **Virchow und Guttstadt.** Die Anstalten der Stadt Berlin für die öffentliche Gesundheitspflege und den naturwissenschaftlichen Untersicht. Berlin, 1886. p. 71.
115. **v. Pettenkofer, M.** Zum gegenwärtigen Stand der Cholerafrage. München und Leipzig, 1887.
116. **Pistor.** Das öffentliche Gesundheitswesen in Berlin, 1882–5. 1887. p. 57.
117. **Soyka.** Zur Aetiologie des Abdominaltyphus. Arch. f. Hyg., VI, 1887, p. 260.
118. **v. Pettenkofer, M.** Der epidemiologische Theil des Berichtes über die Thätigkeit der zu Erforschung der Cholera im Jahre 1883 nach Aegypten und Indien entsandten deutschen Commission. München und Leipzig, 1888.
119. **Almquist, E.** Ueber Einfluss von Jahreszeit und Witterung auf das Auftreten von Infektionskrankheiten mit besonderer Berücksichtigung der localen Epidemieen. Zeit. f. Hyg., V, 1888, p. 1.
120. **Goldberg, B.** Der Einfluss des Witterungsganges auf vorherrschende Krankheiten und Todesursachen. Ergänzungshefte zum Centr. f. allgem. Ges. II, 1889, p. 317.
121. **Magelsen.** Ueber die Abhängigkeit der Krankheiten von der Witterung. Leipzig, 1890.
122. **Davidson, A.** Geographical Pathology. N. Y., 1892.
123. **Woodhead, G. S.** Minutes of Evidence, Royal Commission on Metropolitan Water Supply, London, 1893, p. 506.
124. **Körösi, J.** Statistik der infektiösen Erkrankungen in den Jahren 1881–91 und Untersuchung des Einflusses der Witterung. Berlin, 1894.
125. **Fodor, J.** Hygiene des Bodens. Weyl's Handbuch der Hygiene, I, 1896, p. 194.
126. **Jessen, F.** Witterung und Krankheit. Zeit. f. Hyg., XXI, 1896, p. 287.
127. **Knoevenagel, O.** Studien über Krankheitsdispositionen und über Genius epidemicus. Deuts. Viertelj. f. öffentl. Gesundheitspflege, XXVIII, 1896, p. 298.
128. **Baker, H. B.** The Etiology and Pathology of Typhoid Fever. Twenty-fourth Annual Report of the Secretary of the S. B. H. of Michigan, 1897, p. cxlii.
129. **Berger, H.** Die Bedeutung des Wetters für die ansteckenden Krankheiten. Therapeutische Monatshefte, XII, 1898, pp. 139, 201.
130. **Ruhemann, J.** Meteorologie und Infektionskrankheiten. Zeitschrift für Diätetische und Physikalische Therapie, I, 1898, p. 312.
131. **Weichselbaum, A.** Epidemiologie. Weyl's Handbuch der Hygiene, IX, 1899, p. 441.
132. **Curschmann, H.** Typhoid Fever and Typhus Fever. Nothnagel's Encyclopedia of Practical Medicine. English Translation, edited by Osler. Phil., London, 1901.

EXPLANATION OF THE PLATES.

Plates I.–VIII. are based upon the statistics given on pp. 540–566, as is stated on p. 539. Abscissæ indicate months; ordinates indicate temperatures (shown by broken lines), and also percentages of yearly typhoid-fever mortality (solid lines) except in the curves for Newark, N. J. (Plate VI.), the Empire of India (Plate VII.), and Santiago de Chile (Plate V.), in which deaths, not cases, are indicated.

It is important to remember that the curve of typhoid deaths in each case has been moved back exactly two months from its true position, and that for typhoid cases one month, as is explained on p. 539.

PLATE I.

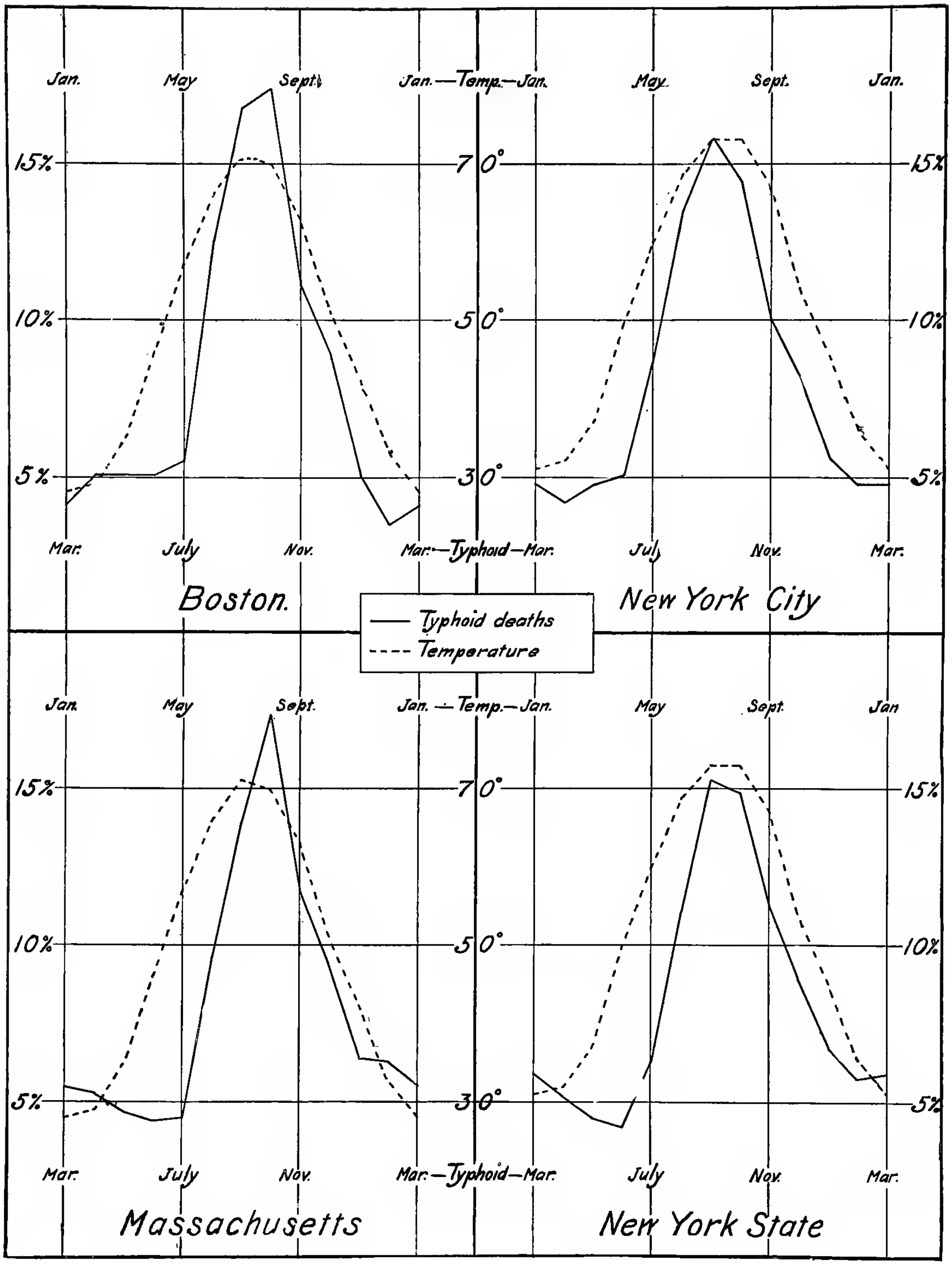

Jan.
May
Sept.
Jan.—Temp.—Jan.
May
Sept.
Jan.
15%
70°
15%
10%
50°
10%
5%
30°
5%
Mar.
July
Nov.
Mar.—Typhoid—Mar.
July
Nov.
Mar.
Boston.
New York City
Typhoid deaths
Temperature
Jan.
May
Sept.
Jan.—Temp.—Jan.
May
Sept.
Jan
15%
70°
15%
10%
50°
10%
5%
30°
5%
Mar.
July
Nov.
Mar.—Typhoid—Mar.
July
Nov.
Mar.
Massachusetts
New York State

PLATE II.

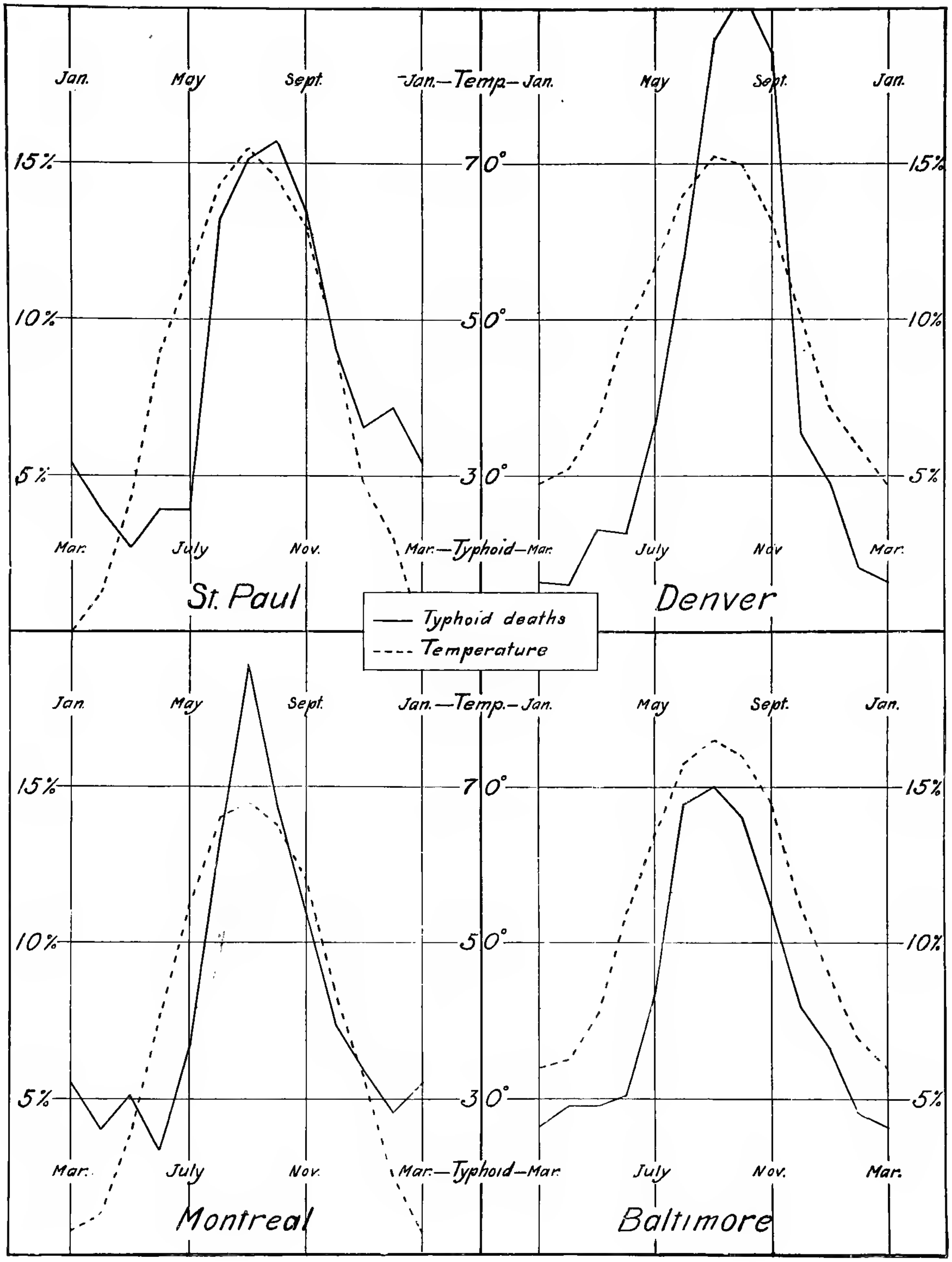

Jan.
May
Sept.
Jan.—Temp.—Jan.
May
Sept.
Jan.
15%
70°
15%
10%
50°
10%
5%
30°
5%
Mar.
July
Nov.
Mar.—Typhoid—Mar.
July
Nov.
Mar.
St. Paul
Denver
Typhoid deaths
Temperature
Jan.
May
Sept.
Jan.—Temp.—Jan.
May
Sept.
Jan.
15%
70°
15%
10%
50°
10%
5%
30°
5%
Mar.
July
Nov.
Mar.—Typhoid—Mar.
July
Nov.
Mar.
Montreal
Baltimore

PLATE III.

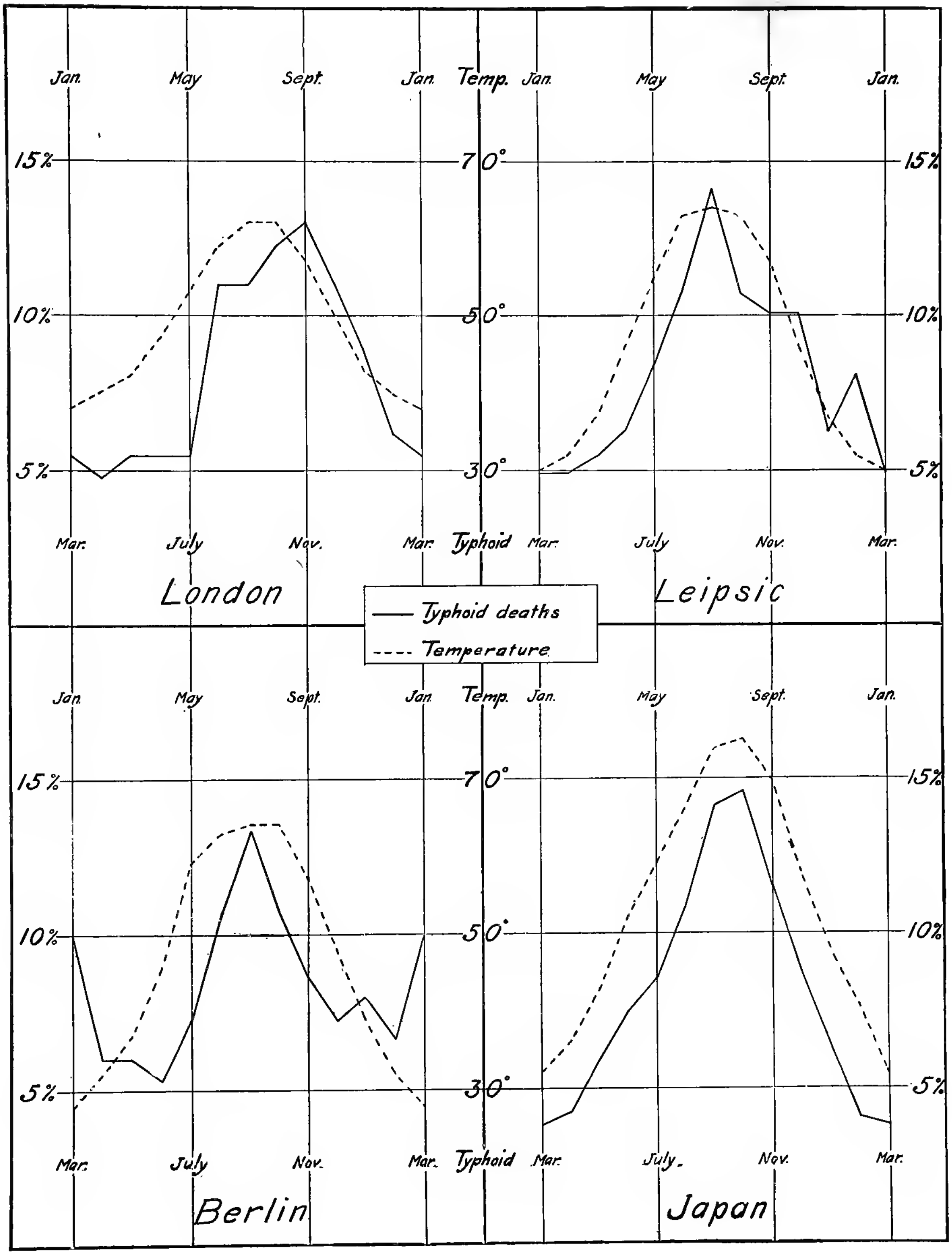

Jan.
May
Sept.
Jan.
Temp.
Jan.
May
Sept.
Jan.
15%
70°
15%
10%
50°
10%
5%
30°
5%
Mar.
July
Nov.
Mar.
Typhoid
Mar.
July
Nov.
Mar.
London
Leipsic
Typhoid deaths
Temperature
Jan.
May
Sept.
Jan.
Temp.
Jan.
May
Sept.
Jan.
15%
70°
15%
10%
50°
10%
5%
30°
5%
Mar.
July
Nov.
Mar.
Typhoid
Mar.
July.
Nov.
Mar.
Berlin
Japan

PLATE IV.

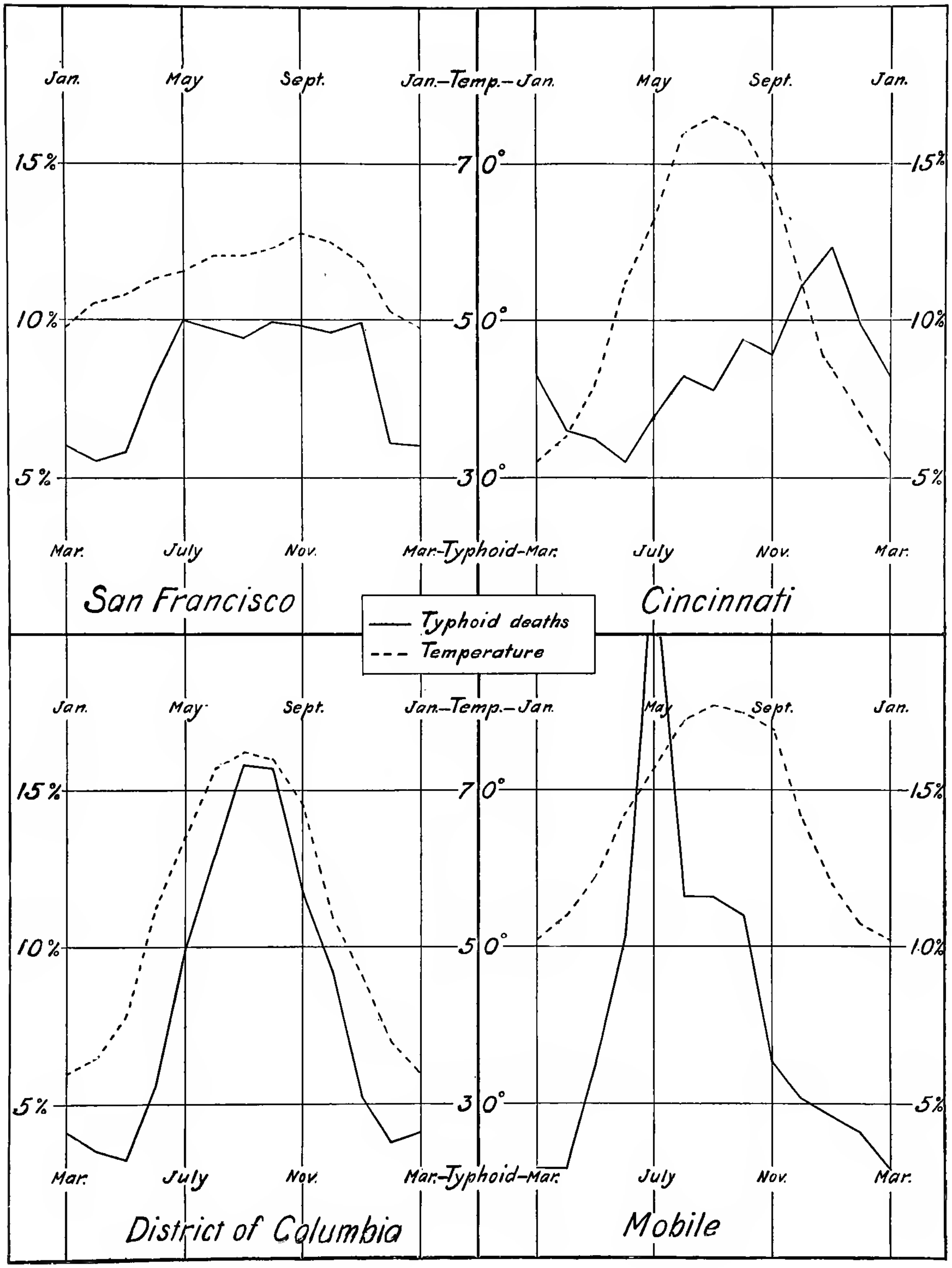
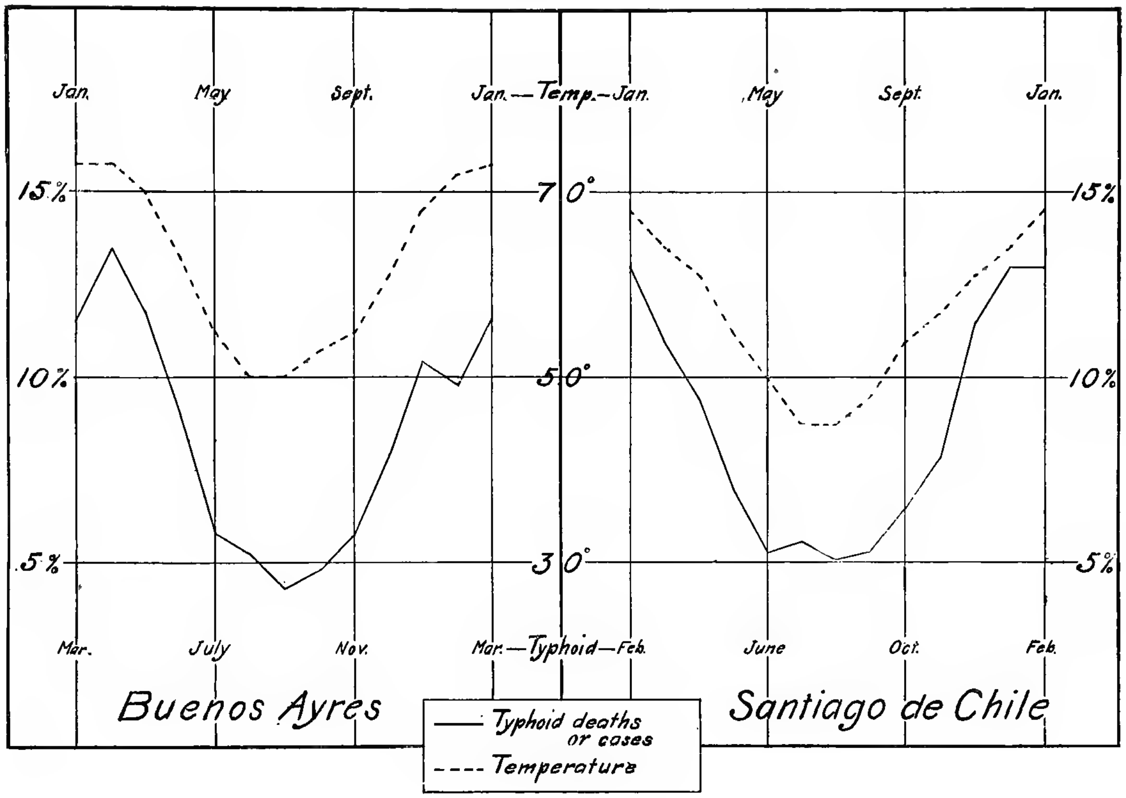

Jan.
May
Sept.
Jan.–Temp.–Jan.
May
Sept.
Jan.
15%
70°
15%
10%
50°
10%
5%
30°
5%
Mar.
July
Nov.
Mar.–Typhoid–Mar.
July
Nov.
Mar.
San Francisco
Cincinnati
Typhoid deaths
Temperature
Jan.
May
Sept.
Jan.–Temp.–Jan.
May
Sept.
Jan.
15%
70°
15%
10%
50°
10%
5%
30°
5%
Mar.
July
Nov.
Mar.–Typhoid–Mar.
July
Nov.
Mar.
District of Columbia
Mobile

PLATE V.


Jan.
May
Sept.
Jan.—Temp.—Jan.
May
Sept.
Jan.
15%
70°
15%
10%
50°
10%
5%
30°
5%
Mar.
July
Nov.
Mar.—Typhoid—Feb.
June
Oct.
Feb.
Buenos Ayres
Santiago de Chile
Typhoid deaths or cases
Temperature

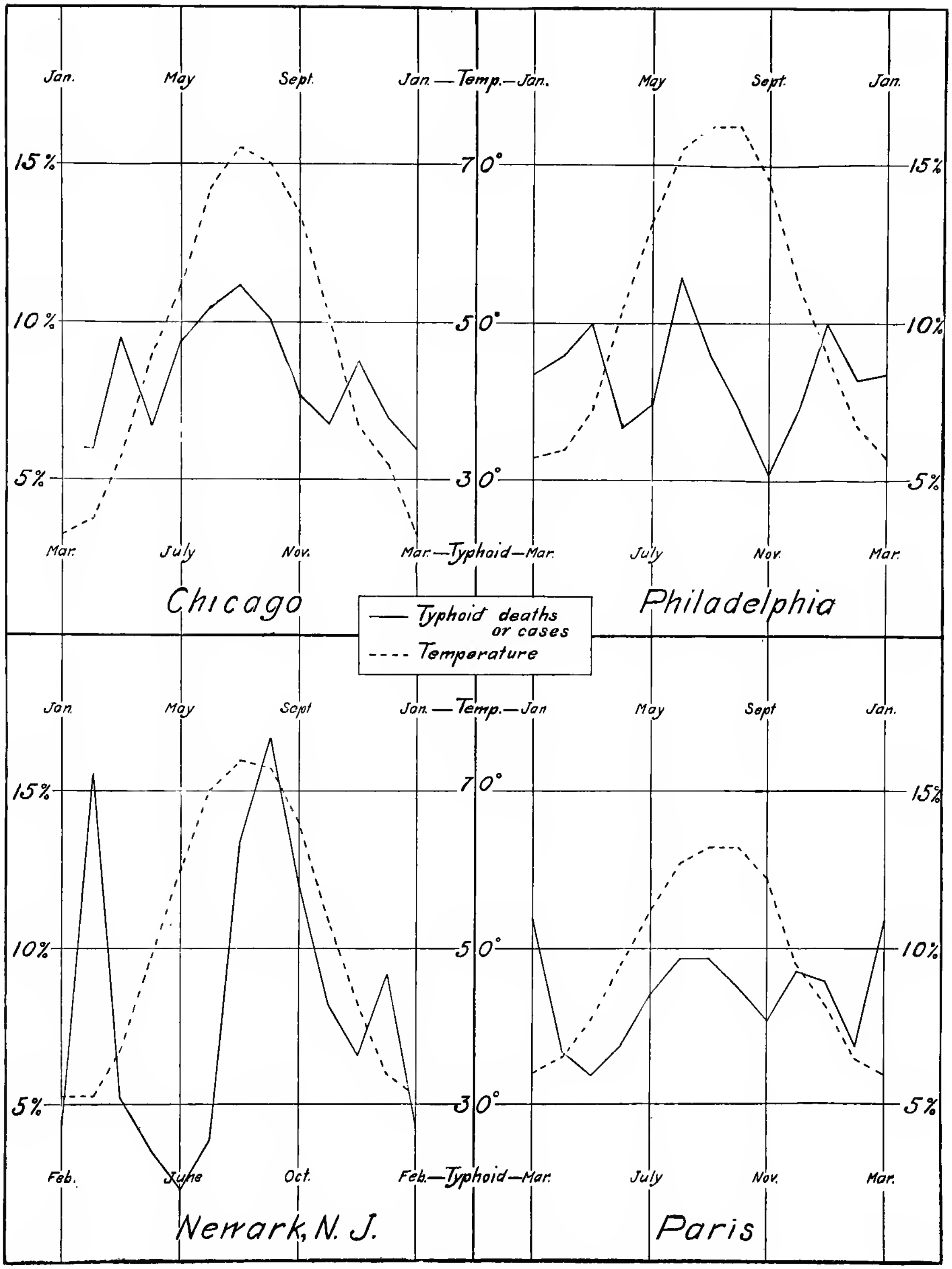
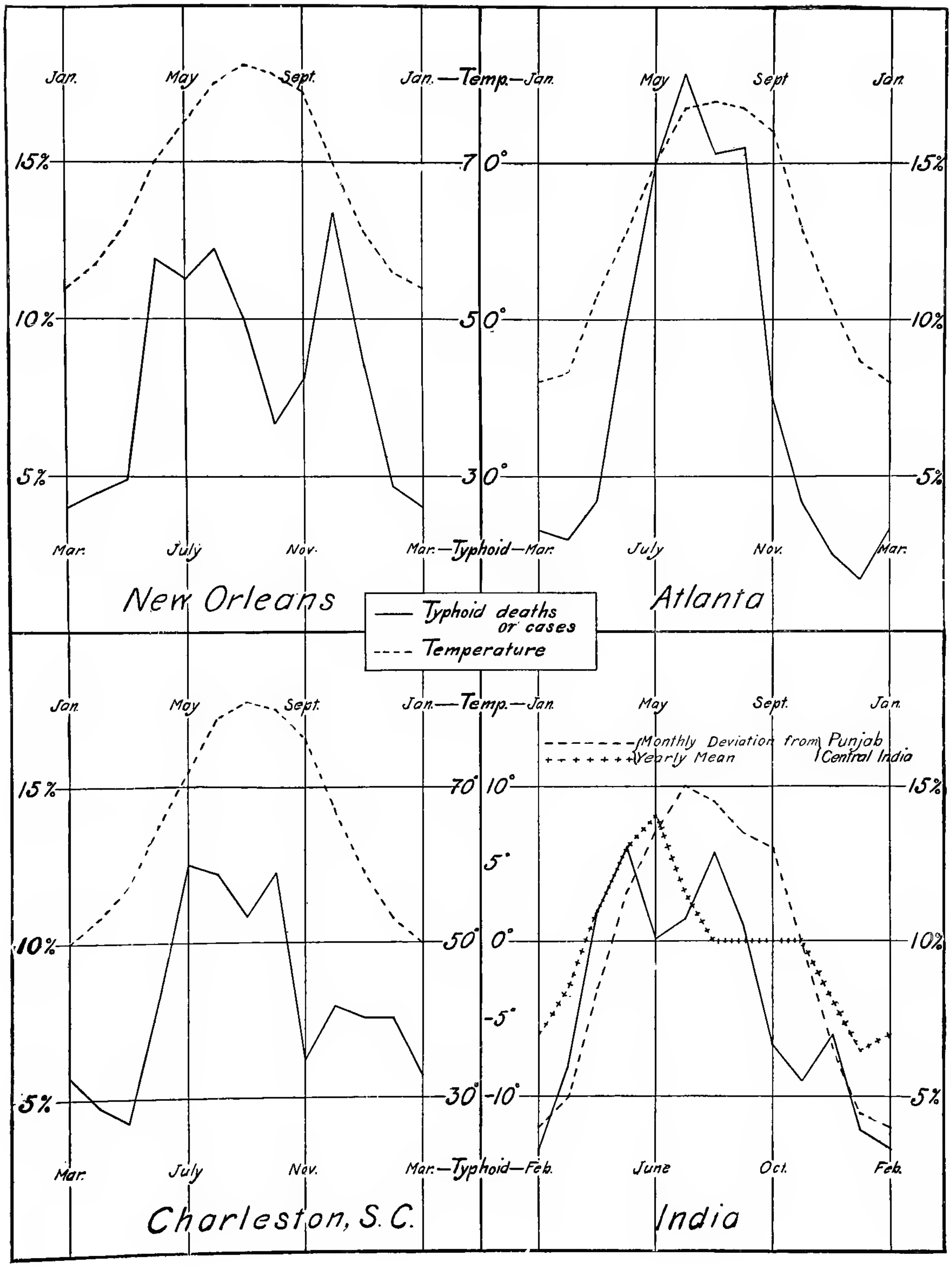
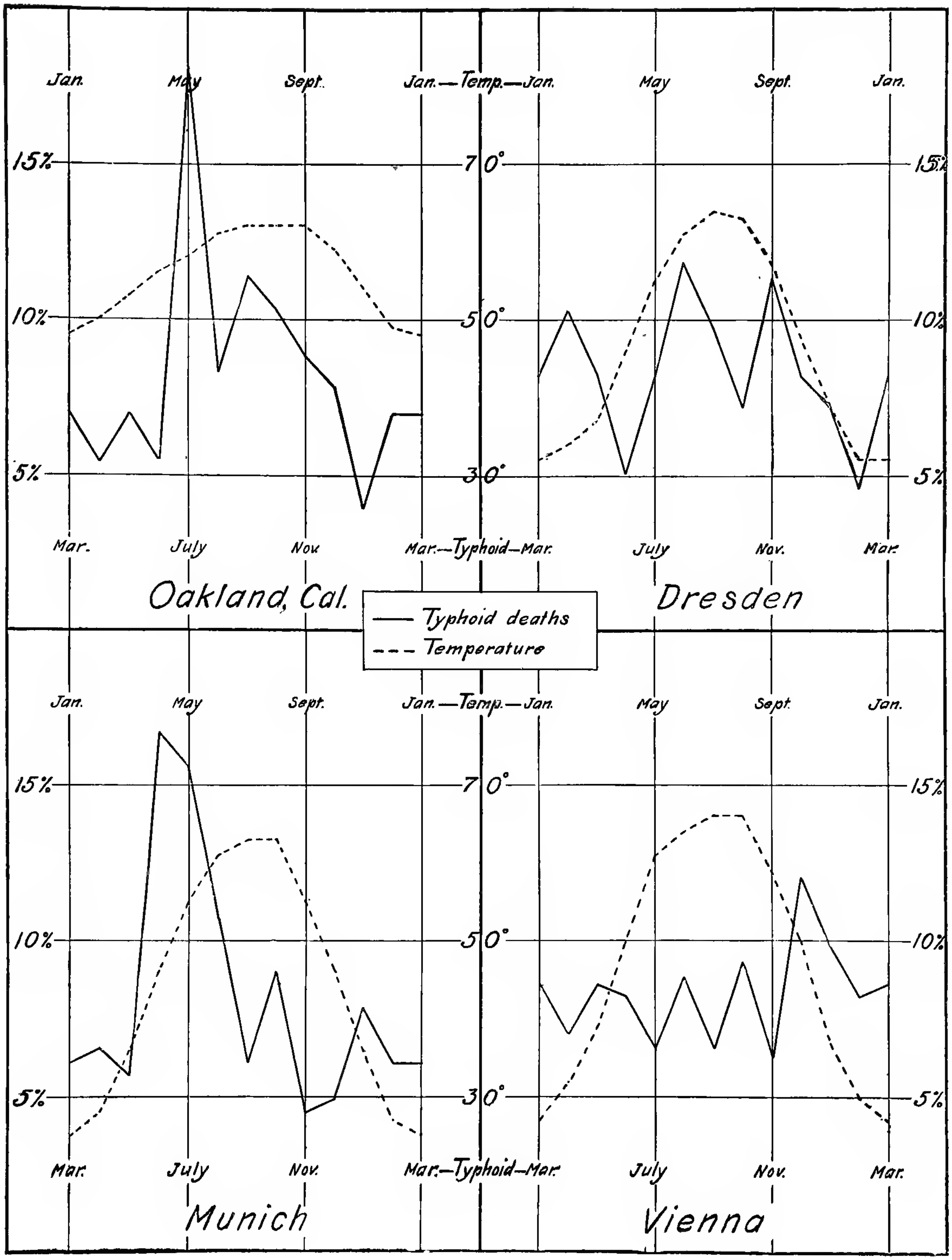

Jan.
May
Sept.
Jan.—Temp.—Jan.
May
Sept.
Jan.
15%
70°
15%
10%
50°
10%
5%
30°
5%
Mar.
July
Nov.
Mar.—Typhoid—Mar.
July
Nov.
Mar.
Chicago
Philadelphia
Typhoid deaths or cases
Temperature
Jan.
May
Sept
Jan.—Temp.—Jan
May
Sept
Jan.
15%
70°
15%
10%
50°
10%
5%
30°
5%
Feb.
June
Oct.
Feb.—Typhoid—Mar.
July
Nov.
Mar.
Newark, N. J.
Paris

PLATE VII.


New Orleans
Atlanta
Charleston, S.C.
India
Typhoid deaths or cases
Temperature
Jan. May Sept. Jan. —Temp.— Jan. May Sept Jan.
Mar. July Nov. Mar. —Typhoid— Mar. July Nov. Mar.
15%
10%
5%
70°
50°
30°
Jan. May Sept. Jan.—Temp.—Jan. May Sept. Jan.
Mar. July Nov. Mar.—Typhoid—Feb. June Oct. Feb.
Monthly Deviation from Yearly Mean
Punjab
Central India
10°
5°
0°
-5°
-10°


Jan.
May
Sept.
Jan.—Temp.—Jan.
May
Sept.
Jan.
15%
70°
15%
10%
50°
10%
5%
30°
5%
Mar.
July
Nov.
Mar.—Typhoid—Mar.
July
Nov.
Mar.
Oakland, Cal.
Dresden
Typhoid deaths
Temperature
Jan.
May
Sept.
Jan.—Temp.—Jan.
May
Sept.
Jan.
15%
70°
15%
10%
50°
10%
5%
30°
5%
Mar.
July
Nov.
Mar.—Typhoid—Mar.
July
Nov.
Mar.
Munich
Vienna

MEMOIRS

OF

THE AMERICAN ACADEMY

OF

ARTS AND SCIENCES

MDCCLXXX.

VOL. XII.

CAMBRIDGE:
JOHN WILSON AND SON.
University Press.
AUGUST, 1902.

CONTENTS.